LEVEL II

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COST AND TRAINING EFFECTIVENESS ANALYSIS IN THE ARMY LIFE CYCLE SYSTEMS MANAGEMENT MODEL

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U. S. Army
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Individual Training and Combat Unit Training

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FOREWORD

The Army is aware of the increasing importance of training and manpower estimation throughout the life cycle process. Dollar and manpower requirements are fixed very early in system development but their full impact is often not apparent until years later. For this reason, improved cost and training effectiveness analysis (CTEA) has become a major Army need. Guidance exists for what analyses are desired, but the state-of-the-art in supporting technology has not kept up with demands for increasingly precise estimates. As a result, ARI initiated a research program on CTEA in 1976 which was concerned with the early estimation of training media, methods, and costs. In 1978 the program was expanded to include training estimation problems during a weapon life cycle. Because the developmental history of no two systems is identical, the present contract was designed too pull together methods developed to deal with individual cases and produce a systematic procedural guide for an Army analyst tasked with CTEA performance. The result of the effort is in two volumes. The first examines CTEA requirements in the life cycle, the available techniques for each analysis point, and the R&D deficiencies. The second is a user's guide implementing the first volume into a step-by-step procedure for CTEA performance using actual field data sources and examples. This research is in response to Army project 2Q263742A794 and special needs of the Directorate of Training Developments, Ft Bliss, Texas.

Joseph Zeidner

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BRIEF

Requirement:

During the acquisition of Army materiel systems as defined by the Life Cycle Systems Management Model (LCSMM) there is a continuing requirement for information on the cost and effectiveness of training personnel to operate and maintain the system. At a number of key points, decision makers need reports, the result of formal cost and training analyses (CTEA). These CTEA evaluate both the development of training systems to support the materiel system and the hardware to assess the impact of the system on personnel capabilities. Army analysts currently charged with conduct of CTEA require workable methods suitable to the particular situation to perform these analyses in a timely manner and to obtain reasonable, accurate recommendations consistently. Therefore, this research was undertaken with the objective of providing Army analysts with a performance guide for the conduct of CTEA at each stage of the LCSMM.

Procedure:

Available methods were identified for performance of CTEA components. The methods were catagorized using a general CTEA model derived from key analyst questions. If the answers to the questions are negative, the analyst is routed to a rank ordered set of methods to generate the missing information. If the answers are positive the analyst is routed to the next operation required by CTEA regulations. The process is continued until a complete analysis is performed. New methods were generated where existing techniques proved inadequate and the complete process incorporated in a user guide.

Findings:

Systems may be fielded with most, some, little, or none of the data described by Army doctrine. Six basic data conditions and sequences were found as follows: (1) no task list and no training program, (2) task list but no training program, (3) training program but no alternatives and no effectiveness data, (4) training program with effectiveness data but no alternatives, (5) alternative training programs but no effectiveness data for all alternatives, and (6) training program alternatives and effectiveness data. Methods in current use were found that could contribute useful information covering one or more of these situations and were within the state-of-the-art of CTEA conducted in the Army

Three methodological deficiencies were found. Use of historical data is hampered because there is no consolidated data bank or base that describes tasks functionally, behaviorally, and in terms of training. Second, existing methodology does not thoroughly address trainability (e.g., Can the available personnel be trained to perform the tasks at the required level of proficiency, given the proposed hardware configuration?). The third gap was in cost models. Costs of unit training were omitted in even the most comprehensive methods examined.

Utilization of Findings:

A CTEA Performance Guide, a fully proceduralized manual, was prepared to provide guidance for CTEA analysts. The Performance Guide contains step-by-step instructions for the selection, application, and implementation of the process method(s). It includes guidance for synthesizing methods on the basis of inputs available, issues, and other constraints as well as strategies for dealing with the various situations. Instructions for using the processes are complete making it unnecessary to procure source documents. The procedures are illustrated with comprehensive examples of their use. The guide is currently being tested in the performance of two Army CTEAs.

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COST AND TRAINING EFFECTIVENESS ANALYSIS IN THE ARMY LIFE CYCLE SYSTEMS MANAGEMENT MODEL

The Army's Life Cycle System Management Model (LCSMM) defines the process by which Army materiel systems are acquired. It was designed to ensure that all aspects of the system are considered during the acquisition process including personnel and training requirements. Cost and training effectiveness analysis (CTEA) provides to decision makers information about how training is influenced by and influences the characteristics of the developing system. CTEA evaluates the development of training systems to support the materiel system and the evolution of a materiel system compatible with personnel and training capabilities.

OBJECTIVE

The objective of this research was to provide Army analysts with a performance guide for CTEA at each stage of the LCSMM. The attainment of this objective required:

- Determination of points in the LCSMM at which CTEA are needed.
- Assessment of the utility of existing methods for CTEA at each point.
- Adaptation of methods to each LCSMM stage where CTEA are needed.
- Development of methods for areas where existing ones are not adequate.
- Identification of input information required and available at each point.
- Estimation of the impacts of missing or degraded information on the CTEA.
- Synthesis of a general model for CTEA in the LCSMM.
- Production of a CTEA Performance Guide for Army analysts.

CTEA SITUATIONS AND STRATEGIES IN THE LCSMM

Several LCSMM events require CTEA information. For example, four cost and operational effectiveness analyses (COEA) are conducted during the LCSMM. CTEA support COEA by providing assessments of alternative ways to train to achieve the desired operational effectiveness of the system as well as providing the cost of each proposed alternative. At least four CTEA are needed to support the COEA and additional CTEA are beneficial to support training development decisions.

Our examination of the LCSMM decision requirements revealed the need for a more detailed analysis of the CTEA job to be performed by the Army analyst.

Materiel systems do not progress through the LCSMM in look-step fashion. Systems may be fielded with most, some, little, or none of the data described in Army doctrine, and the data are not necessarily generated in the prescribed sequence. If we wished to give the Army analyst the wherewithal to perform a CTEA, we had to use as guidance (1) the decision to be rendered on the basis of the CTEA information and (2) the data available to conduct the CTEA. These two factors are the boundaries for CTEA methodology regardless of the point in the LCSMM.

Some data conditions and sequences are more likely to occur than others. For example, the lack of a task list or training program implies the lack of training effectiveness data. Litton identified six input-data situations as:

1. No task list and no training program,

2. Task list but no training program,

3. Training program but no alternatives and no effectiveness data,

4. Training program with effectiveness data but no alternatives,

5. Alternative training programs but no effectiveness data for all alternatives, and

6. Training program alternatives and effectiveness data for all alternatives.

Depending upon the data situation the analyst needs a different strategy to perform each CTEA. None of the CTEA methods unearthed in Litton's literature review provided all information required for decisions at any point in the LCSMM. However, detailed examination of the techniques, steps, or processes within the methods (i.e., the elements from which the methods are built) showed that each method contributed to the CTEA job to be performed. Some methods contributed more elements within some data situations than others. For example, informal, expert-judgment methods in current use generate task lists if none are available. Formal analytic models for prediction of training programs, however, are superior to the judgmental models if task lists already exist.

Litton devised a general model for CTEA to guide the analyst in assessing the data situation and in selecting CTEA processes. The model leads the analyst through questions concerning the availability of task lists and training programs, including alternative training programs. Following these are the estimation of effectiveness, cost analysis of training program alternatives, cost effectiveness comparisons of training program alternatives, and resolution of issues. Each situation identifies a set of required CTEA processes and suggests an approach to meet the CTEA objectives. Litton designed strategies to guide the selection of the processes and conduct of the CTEA.

SELECTION OF CTEA PROCESS METHODS

Powerful methods applicable to CTEA and the whole manpower, personnel, and training side of acquisition via the LCSMM have been developed and await broad application and refinement.

An examination of the set of CTEA methods, the constraints on them, and the CTEA strategies led to the following criteria for the selection of the methods to be included in the CTEA Performance Guide:

- o The method must have either demonstrated or face validity.
- o The method selected must be usable in the present rather than at some unspecified time in the future.
- o Because all six strategies are required to meet the requirements identified by the general CTEA model, methods must be selected or developed to fully implement each strategy.

In addition, alternative methods were selected for each process required by a strategy. Automated methods were selected whenever possible to meet constraints that arise from personnel resources available to perform CTEA.

The methods that have processes useful in the LCSMM are:

- o Training Efficiency Estimation Model (TEEM; Jorgensen and Hoffer, 1978),
- o Training Consonance Anaysis (TCA; Hawley and Thomason, 1978),
- o Training Effectiveness, Cost Effectiveness Prediction (TECEP, also known as TAEG No. 16; Braby et al., 1975),
- o Army CTEA Methods in Current Use:

  DIVAD Gun CTEA,

  Improved Hawk (Hawk PIP) Training Development,

  Roland Training Development,

  Improved TOW Vehicle (ITV) CTEA,

  Diagnostic Rifle Marksmanship Simulators (DRIMS) CTEA, and

  Methods for the Analysis of Training Devices and Simulators (TRAINVICE).

Extant CTEA methodology contained three weaknesses. First, use of historical data was hampered by inadequate definition of analogous tasks (i.e., tasks in a fielded system functionally and behaviorally similar to tasks in the proposed system). Second, the existing methodology did not thoroughly address the issue of trainability, one of the estimations needed in the LCSMM. Third, the most thorough cost analysis model omitted costs of training in units.

Litton devised methods to meet these methodological needs. First, our analogous task method (ATM) was developed to take advantage of information obtained in the process of training soldiers on fielded weapons systems. The method is applied on a task-by-task basis with an overall estimate of training effectiveness. The analogous task method has six steps: (1) definition of the

critical tasks to be performed on the developing system (the target tasks); (2) classification of the target tasks to provide a basis for finding the analogous tasks; (3) analogous task identification and selection; (4) assessment of training for the analogous tasks; (5) generation of estmates of training for the target tasks; and (6) aggregation of the effectiveness and cost measures across all tasks to obtain a picture of training for the developing system as a whole. ATM is illustrated in Figure II-2. Each rectangle represents a step in the process, while the processes indicated in the circles show the relationship of the process to other processes in a general CTEA model to be presented later.

The second methodology devised by Litton, trainability analysis, is needed to examine the interactions among tasks, training program alternatives, and personnel characteristics. Once tasks have been identified and alternative means of training those tasks have been predicted or developed, it is necessary to determine that, given the characteristics of the personnel who will man the system, the tasks can be trained to required levels of proficiency. Our literature review unearthed no explicit method for trainability analysis, therefore we proposed a process to use as an interim technique until further research is conducted.

Litton's third methodological development expanded the TECEP cost model to cover costs of institutional field training and training in Army units. The Litton cost model is intended to aid the CTEA analyst in preparing recommendations to the decision maker regarding choices among alternatives. It is not intended for budgetary purposes. The Litton model does, however, capture pertinent institution and unit costs.

Four methods developed for the Air Force were considered but not incorporated in the model at present. They require substantial revision to make them suitable for Army use. These methods are automated in total or in part and use consolidated data bases. They are:

- Coordinated Human Resources Technology (CHRT; Goclowski et al., 1978),
- Method of Designing Instructional Alternative (MODIA: Carpenter-Huffman et al., 1977),
- Digital Avionics Information System: Training Requirements Analysis Model (DAIS/TRAMOD); Czuchry et al., 1978),
- B-1 Bomber Systems Approach to Training (B-1 SAT; Sugarman et al., 1975).

The Training Developer's Decision Aid (Pieper et al., 1979) method was developed for the Army and it is generally applicable to CTEA. It has not yet been fully developed, however, and some problems in implementation remain, especially the generation of task lists. Because of the extent of arbitration in the logic of the method, an extensive validation effort is necessary to demonstrate the usefulness and precision of its outputs. Available descriptions of the method are not complete enough to permit its inclusion in the CTEA Performance Guide.

SPECIFICATION FOR THE CTEA PERFORMANCE GUIDE

The means for synthesizing CTEA methods from available process methods have been provided, but guidance for the application of those means as well as for the implementation of the selected process methods must also be provided. The CTEA Performance Guide (a separate volume) provides such guidance.

The CTEA Performance Guide:

- Contains guidance for conducting CTEA on the basis of inputs available for analysis, issues to be resolved, and other constraints on the analysis, such as the skills and numbers of CTEA personnel and the time available for performance.
- Contains strategies for dealing with the various input-data situations that are a function of both the phasing of LCSMM itself and the deviations from the LCSMM that any particular acquisition program exhibits.
- Contains complete instructions for each process method so that the unavailability of source documents will not impede the conduct of a CTEA.
- Provides examples or illustrations of the applications of process methods.

GENERAL RECOMMENDATIONS

Results of the CTEA literature review, synthesis of methods and guidebook preparation lead to the following recommendations:

- Program TEEM, TCA, and the Litton Cost Model before the CTEA Performance Guide is released to CTEA analysts. Be sure that programs, suitable machines, and reasonable interfaces with CTEA analysts are provided.
- Develop and adapt one or more of the automated Air Force methods discussed above for Army Training Developments and CTEA.
- Develop means, including explicit contractual requirements, to assure that all developmental data needed by CTEA analysts become available in timely fashion.
- In CTEA study directives, include specifications of CTEA timing or phasing in conformity with the CTEA locations described in Section II of this report.
- In CTEA study directives, specify CTEA requirements on the basis of a realistic appraisal of the actual status of the acquisition program of interest rather than by reference to the LCSMM.

These powerful CTEA and acquisition process methods of the future, if they are realized by the Army, will probably all be computer based. This feature promises not only greatly enhanced efficiency in the processing of information but almost certainly a degree of precision not now achievable. It is possible that such an increase in the efficiency and precision of information processing could both increase the effectiveness of systems and reduce the time required to acquire them.

SECTION I
INTRODUCTION

The acquisition process for military weapon systems moves through several phases beginning with the formulation and examination of alternative concepts for achieving desired ends and finishing with deployment of a system with demonstrated capability to achieve those ends at an acceptable cost. That is, the acquisition process ends with such a system if at every step the right decisions are made. Making the right decisions depends on timely and valid information including information concerning cost and effectiveness of training programs to support weapon system operation and maintenance. Cost and training effectiveness analysis (CTEA) provides that training system information.

CTEA have long been performed for existing weapon systems toward the same purpose: organization and presentation of information to enable decision makers to select from among alternative training approaches those that increase man-machine system performance within cost constraints. Weapon system training effectiveness analysis identifies training problems and proposes solutions to those problems.

The Army's Life Cycle System Management Model (LCSMM), the process by which the Army materiel systems are acquired, was designed to ensure that all aspects of the weapon system are considered during the acquisition process. These aspects include integration of user and trainer requirements and developments with the parent weapon system development. Moreover, it was intended to allow the trainer to consider cost-effective training options before final weapon system fielding. However, the emphasis in the LCSMM has been on events concerned with the parent system.

It is essential that the personnel and training impacts be known early. Therefore, questions of estimated training program effectiveness and estimated cost need early answers. The answers are highly sensitive to changes in the development of the parent system. As with the parent system, testing is needed for trade-offs between training on operational equipment, training simulators and devices, and other training issues. Frequently no such testing of simulation, training equipment, or training programs is accomplished. When testing is done, it occurs late in the cycle or after the system is fielded. Late testing fails to ensure cost-effective training: the user should be confirming the effectiveness of training during late stages, not starting its assessment.

The training developer lacks guidelines and procedures for the concurrent development of training programs with the development of the parent system. The problem, then, is to furnish a complete, detailed roadmap on the best way to integrate training requirements into the materiel development cycle and provide tools for trade-off decisions at each critical training program decision point. The purpose of this research is to provide the CTEA analyst with tools to organize, select, and analyze data for decision making.

CTEA methodology in the LCSMM must adapt to an array of data types that vary in precision, accuracy, and completeness. Some CTEA methods require empirical performance data, others human factors information, and still others require only task descriptions. These three CTEA styles represent a continuum in data

requirements. CTEA methodology applicable in the LCSMM cannot be drawn exclusively from any one of these styles. It must synthesize methods suited to the types of data available throughout the LCSMM and responsive to information needed for decision making. CTEA in the LCSMM needs methodology capable of replacing input data at successive stages as more definite data become available. The CTEA methodology must be iterative and usable as a tool in cost-effectiveness estimation and in hypothesis testing. At each application, training requirements must be forecast, alternatives that offer probable cost-effectiveness selected, and results of prior estimations tested to gradually refine and improve training.

CTEA is a method for defining training alternatives, comparing those alternatives, and defining the proficiency obtainable with each training-hardware combination. That is, CTEA must be:

- prescriptive - identify training program elements likely to be effective;
- diagnostic - identify weaknesses in training programs; and
- predictive - define the probable effectiveness and cost of training programs.

CTEA methodology, therefore, is more than a means for differentiating among alternatives (the hypothesis testing function). At early stages of the acquisition cycle, CTEA methods need to identify existing data to define training options. In this forecasting role, CTEA predicts an array of training alternatives. CTEA must reveal training deficiencies and recommend solutions. In late stages, CTEA methods must continue forecasting and diagnosis and must differentiate among alternatives. Changes in threat, tactics, and operations continually influence system performance. CTEA methodology must be capable of continually assessing these impacts on effectiveness, identifying corrective options, and guiding modifications.

In summary, the objectives of CTEA in the LCSMM are to:

- Ensure that training processes are initiated early in the LCSMM and are accomplished in parallel with combat developments processes;
- Ensure that a training subsystem is developed with the same degree of scientific application as is the parent hardware system;
- Ensure that training system alternatives are considered; and
- Provide decision makers with information at critical points concerning the training and hardware system.

Research Objective and Overview

The objective of this research was to provide Army analysts with a performance guide for CTEA at each stage of the LCSMM. Figure I-1 represents an overview of the conduct of this research. A description of the acquisition process,

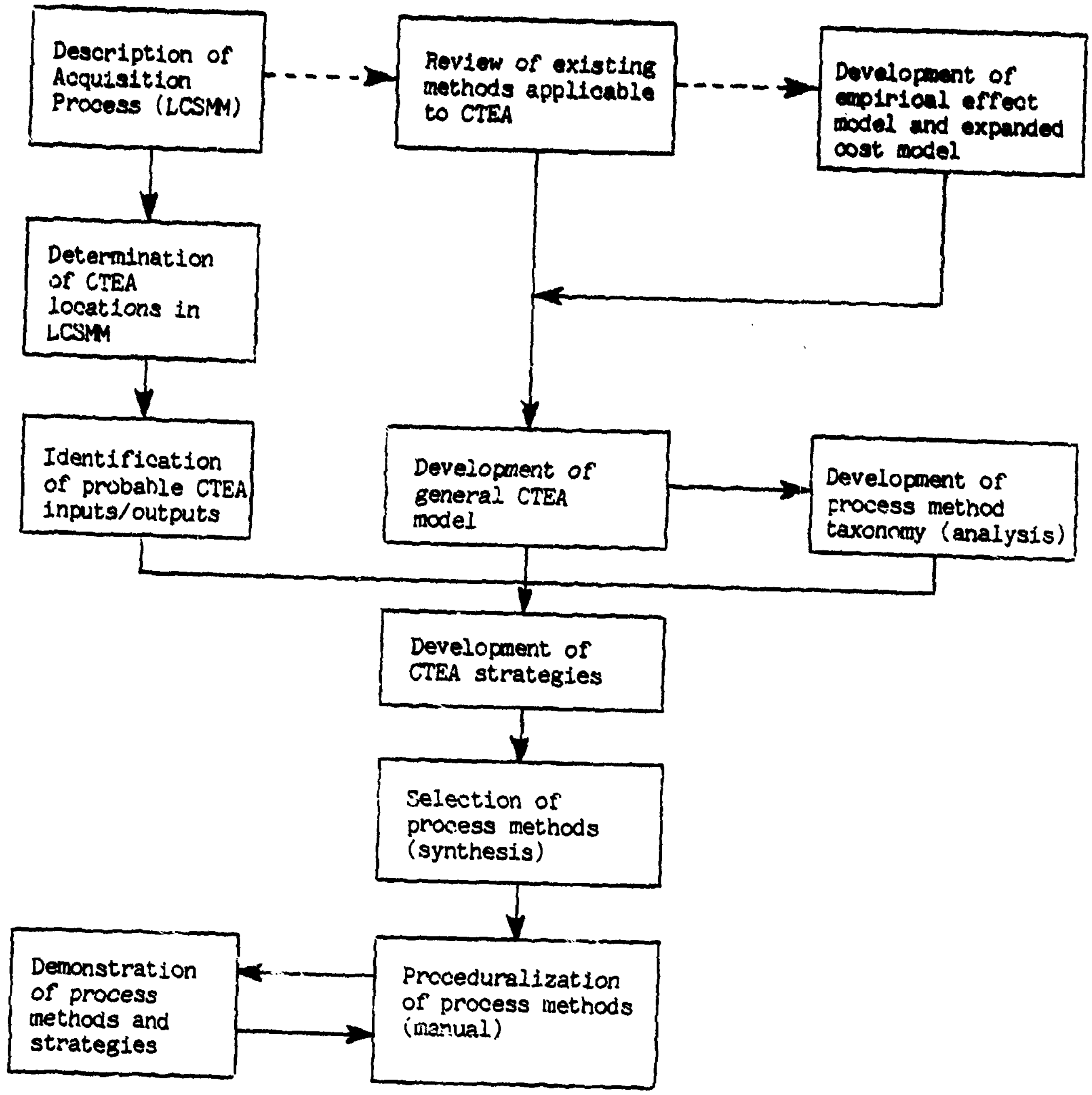

Figure I-1

OVERVIEW OF CTEA RESEARCH

the Army's LCSMM, was first developed. From the description of the LCSMM were derived locations of CTEA. The CTEA locations imply the probable input and output information of the CTEA, such as CTEA output required for Cost and Operational Effectiveness Analysis (COEA). Existing CTEA methods, or methods applicable to CTEA objectives, were reviewed to determine their suitability for CTEA during weapon system development. In addition, CTEA methods were developed for areas that existing methodology failed to cover adequately. The result is a general CTEA model that synthesizes a family of CTEA methods, each of which is applicable at a different point in the LCSMM. The methods that appeared most applicable were selected for inclusion in the user's manual. The selected methods were written in procedural terms and were demonstrated using examples gleaned from Army analyses of developing weapon systems.

Organization of the Report

Section II of this report contains an overview of the LCSMM, an examination of the requirements and purposes of CTEA within the LCSMM, and recommended locations for CTEA in the LCSMM. This section defines the problems of CTEA for which solutions are proposed in the following section.

Section III summarizes existing CTEA and CTEA-applicable methods.

Section IV presents methods devised by Litton during the present research to augment existing methods.

Section V discusses a general CTEA model for use in the LCSMM and synthesizes the material selected for the user's manual. It examines the constraints on employment of CTEA methods, and explains CTEA strategies.

Section VI offers conclusions and recommendations. It introduces a companion document, <u>The Cost and Training Effectiveness Analysis Performance Guide</u>, which contains procedures for CTEA in the LCSMM and examples of their use.

SECTION II

COST AND TRAINING EFFECTIVENESS ANALYSIS IN THE LIFE CYCLE SYSTEM MANAGEMENT MODEL

The process through which Army materiel systems are acquired is described by the Life Cycle System Management Model (LCSMM), expressed in a 119 event flowchart (Department of the Army, 1975). LCSMM outlines procedures for the development and acquisition of Army systems from concept investigation through ultimate disposal of obsolete systems. It covers coordination of combat development, research and development, production and logistic support, training and personnel requirements, and actions required to develop and maintain the system.

The Integrated Personnel Support (IPS) system is the process by which personnel considerations are integrated into the LCSMM (Department of the Army, 1978). The goal of IPS is to ensure that personnel resources are planned, developed, acquired, tested, and deployed in conjunction with the materiel acquisition process. Personnel resources include the number and characteristics of personnel required to operate, support, and maintain the system, their training, interface with the hardware, human resources development, and other personnel factors.

The military services conduct continuing analyses of the threat and associated friendly mission areas, including military mission needs, capabilities, resources, and technology. Based on their analyses, the services prepare mission element need statements (MENS) for approval by the Secretary of Defense to justify major new system acquisition. MENS contain a "constraints" section for the manpower and resources for the proposed system. Minimization of the number and skill requirements of people needed to operate and support the proposed system is a goal of the planning. Thus, personnel estimates such as the number, skills, training, and occupations required are part of the MENS.

The number and characteristics of personnel estimated for the system influence task and training subsystem design. The training must accommodate the number of personnel, their aptitude levels, and prior training. The type of training depends upon the nature of the personnel who are to be trained.

Approval of the MENS by the Secretary of Defense authorizes the Army to initiate the LCSMM. The process consists of four major phases: Conceptual, Demonstration and Validation, Full-Scale Development, and Production and Deployment. Specificity of the materiel design, personnel considerations, and training vary with the LCSMM phases. Early in the cycle, such as the Conceptual phase, personnel estimates and information on training effectiveness are gleaned from engineering data and general principles of human factors and instructional design. In later phases empirical data are available from developmental and operational tests. During deployment, cost and effectiveness data are collected in field tests. The data increase in accuracy, objectivity, scope, and completeness as the acquisition cycle proceeds.

Several LCSMM events require CTEA information and are influenced by CTEA. Figure II-1 shows the LCSMM locations that produce new or revised input data for CTEA and that require CTEA. For example, four cost and operational effectiveness analyses (COEA) are conducted, one in each major phase. CTEA support COEA

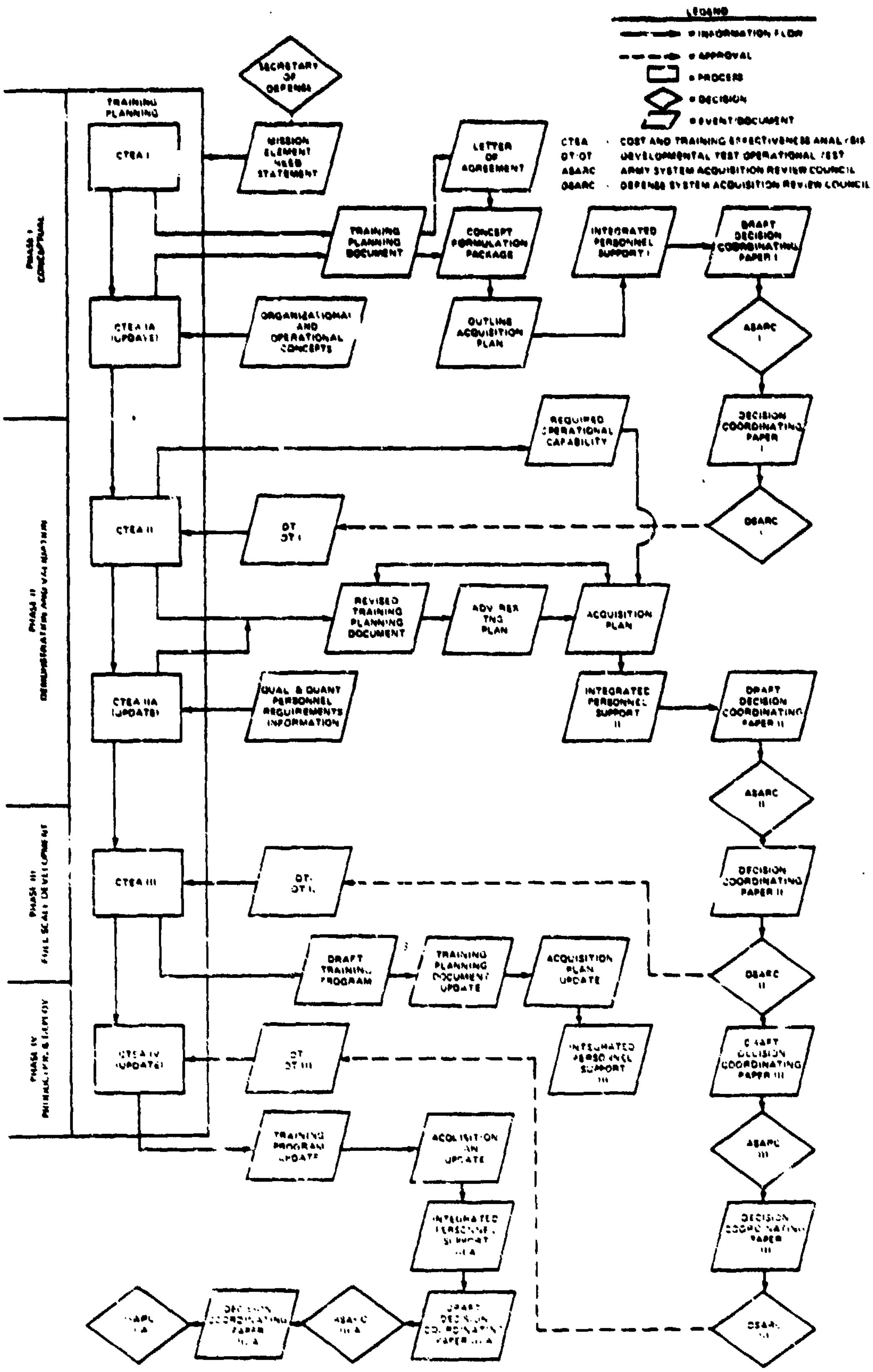

Figure II-1. CTEA in the System Acquisition Process

by providing assessments of alternative ways to train to achieve the desired operational effectiveness of the system (Department of the Army, 1977). At least four CTEA are needed to support the COEA, and, according to the Army regulations cited in this section, additional CTEA are beneficial to support training development decisions.

If CTEA locations in the LCSMM are bound by events that provide new or revised data to CTEA and by events that require, or are influenced by CTEA, then six CTEA are recommended, as shown in Table II-1. Two CTEA are recommended during each of the first two phases, Conceptual and Demonstration and Validation. One CTEA is recommended during each of the two later phases, Full-Scale Development and Production and Deployment. The events that bound the CTEA and reasons for the recommended CTEA locations are described in the remainder of this section.

A. Conceptual Phase

Approval of the MENS by the Secretary of Defense authorizes the Army to initiate the Conceptual Phase. This phase establishes the technical, military, and economic bases for the proposed system and formulates concepts through research and the development of experimental prototypes. It includes the solicitation, evaluation, and competitive exploration of alternative means of achieving the mission.

Several requirements documents are prepared during this phase that need information concerning personnel and training. An early training requirements document is the Task and Skill Analysis (TASA) that describes roughly what the people need to do to operate and maintain the system. Ideally, the TASA contains three categories of tasks: machine functions, human functions, and shared functions. Critical tasks are identified in the human and shared function categories. The critical tasks are likely to require formal training and they guide the training support plan. At this early stage the training support plan focuses on training factors that influence hardware and training device designs to anticipate potential trade-offs. The Outline Individual-Collective Training Plan (OICTP), an element of the training support plan, summarizes expected courses of instruction, changes in existing courses, and training and performance aids for the new system.

Personnel requirements are based on the rough TASA. They include estimates of the number of personnel required, the skills needed, unique mental and physical requirements, and human resources development factors (e.g., morale, organizational climate). Personnel requirements and savings are included as part of the prospective operational effectiveness and costs in the Letter of Agreement (LOA).

The LOA is a document jointly prepared and authenticated by the combat developer and the materiel developer. It outlines their basic agreements for advanced development investigations of the proposed system. Agreements and investigations cover operational, technical, personnel, training, and logistic support concepts. Army regulations demand quantitative estimates in the LOA of operational effectiveness and cost of the new system (Department of the Army, 1979). Thus, cost and effectiveness information is required preceding the LOA.

Table II-1. CTEA in the LCSMM

LCSMM PHASE	CTEA	PRIMARY LCSMM EVENTS YIELDING DATA TO CTEA	ISSUES REQUIRING RESOLUTION
CONCEPTUAL	I	• MENS • INITIATION OF TRAINING PLANNING • INITIATION OF LOGISTICS SUPPORT PLANNING	• TRAINABILITY OF BASIC CONCEPT • COST OF TRAINING • TRAINING PROGRAM ELEMENTS TO BE INCLUDED OR STUDIED
	I A (update)	• LOA • ORGANIZATIONAL AND OPERATIONAL CONCEPTS	• TRAINABILITY OF ALTERNATIVE CONCEPTS • RELATIVE COST EFFECTIVENESS OF TRAINING PROGRAMS OF ALTERNATIVE CONCEPTS
DEMONSTRATION AND VALIDATION	II	• OAP • DT/OT I	• TRAINABILITY • NECESSARY REVISIONS OF TRAINING PROGRAMS • RELATIVE COST EFFECTIVENESS
	II A (update)	• PQQPRI • DCP(IPS)	• TRAINABILITY • TDR • RELATIVE COST EFFECTIVENESS OF REVISED TRAINING PROGRAMS
FULL-SCALE ENGINEERING DEVELOPMENT	III	• NET PLAN • AP • DT/OT II	• PERFORMANCE VERSUS STANDARDS • PERFORMANCE VERSUS HARDWARE AND TRAINING PROGRAM DESIGN, PERSONNEL SELECTION, ETC.
PRODUCTION AND DEPLOYMENT	IV (update)	• TRAINING PLAN UPDATE • DRAFT TRAINING PROGRAM • AP • DT/OT III	• COST EFFECTIVESS OF REVISED TRAINING PROGRAM

Information in the LOA serves as a basis for ensuing documents including Organizational and Operational Concepts, Outline Acquisition Plan, Qualitative and Quantitative Personnel Requirements Information, and Basis of Issue Plan.

- The Organizational and Operational Concepts document describes trade-offs between organizational and operational equipment and personnel.

- The Qualitative and Quantitative Personnel Requirements Information is issued first in tentative or provisional form (TQQPRI or PQQPRI). It provides information concerning the number and skills of personnel required for the operation, support, and maintenance of the proposed system.

- The Basis of Issue Plan (BOIP) indicates the quantity of new or modified equipment for each type of organization and changes in personnel and supporting equipment.

The next major document is the Concept Formulation Package (CFP) which documents that the objectives of the system concept are met. The CFP describes the technical approach, trade-offs, risks, personnel requirements, costs, schedules, and logistic support requirements. It includes the results of a COEA. Thus, a CTEA is needed to provide information assessing alternative ways of training to achieve the desired operational objective. Baseline Cost Estimates (BCE) that document the cost of acquisition and operation, including personnel costs, are developed for the CFP and are refined throughout the acquisition cycle.

The Outline Acquisition Plan (OAP), formerly called the Development Plan, contains plans for the management of the advanced development of the system. The materiel developer prepares the OAP using input from the LOA, CPF, and ICTP. TRADOC, ADMINCEN, and LOGCEN assist with personnel issues that require testing and to identify training requirements. Research on personnel trade-offs and requirements is conducted and the results are incorporated into the OAP.

The Conceptual phase culminates with Milestone I, the first In-Process Review or Army Systems Acquisition Review Council and Defense System Acquisition Review Council (ASARC/DSARC I) authority to proceed with the Demonstration and Validation phase.

CTEA Implications

CTEA in the Conceptual phase need to provide a deliberate assessment and analysis of alternative means of training to achieve the operational effectiveness of materiel systems within a force. Tasks essential to mission accomplishment with alternative system designs vary in the difficulty with which they are performed and trained. Overall operational effectiveness of the system varies as a result. An accurate determination of operational effectiveness must be based on the proficiency likely to be obtained with each design and the cost of training necessary to achieve that proficiency. The CTEA should provide that information for each of the materiel system design alternatives.

A preliminary cost and operational effectiveness analysis is a portion of the LOA. This analysis should "demonstrate that there is a reasonable chance of providing a significant advance in operational capability at an acceptable cost" and should "indicate probable improvement in force effectiveness, probable relative costs and the military need for the proposed system" (Department of the Army, 1977). Moreover, it should "outline the methods and costs involved in obtaining information on critical issues for the CFP COEA" (ibid).

This preliminary CTEA is important in defining the system concept. It compares the training effectiveness and costs of high-risk training elements for each of the alternative materiel systems being explored. It identifies the high-risk and high-cost components as early as possible in the LCSMM. It ensures a complete OICTP by providing known training concepts, strategies, costs, and requirements. This CTEA is prescriptive, stating:

- Unique performance requirements that limit system effectiveness because of low probability of trainability;

- Training program elements that must be included in the training system to enable fielding of a fully effective weapon system; and

- Potential impact of training program omissions because of cost and development risk.

The CTEA should project the consequences of various outcomes in a "trainability risk analysis" and their costs. Where alternative systems are being considered, the cost and trainability risk figure into comparison of the alternatives. Trainability issues are:

- What task groups are exceptionally complex and constitute high training development risk?

- What are the standards of performance for the high risk tasks?

- Which high risk tasks require above average mental and physical ability?

- What are the difficulties in training the target population for each alternative technical approach?

- What training approaches offer the greatest potential for solving each of the high risk training problems?

- What are the high risk training support requirements for each alternative system?

- What are the costs of the high risk training support requirements?

A variety of input data for the CTEA is likely to be available. The MENS specifies the military need and constraints on the manpower and resources. A basic system concept, or alternative system concepts, has been expressed and the TASA and OICTP provide a rough estimate of the tasks and training summary, including the identification of high-risk tasks, decisions on the locations for training, and general statements about the type of training to be conducted.

The output of this preliminary CTEA needs to define the trainability of each alternative given the outline training program, provide the cost of training for each BCE, and provide recommendations for training program elements to be included in the OICTP or examined in research. It should state the training issues to be examined and provide guidance for detailed front end analysis for training program refinement.

An update of the CTEA is recommended as input to the COEA that supports the CFP. The CFP is the culmination of research designed to identify alternative means of satisfying the needs set forth in the MENS. The materiel developer performs engineering analyses, identifies technical approaches and their support, technical and logistical concepts including the provisional QQPRI. The combat developer formulates the BOIP, and together the materiel and combat developers formulate the Organizational and Operational Concepts. The CFP is a compilation of these documents that consider materiel and personnel issues, screening of alternative systems concepts, trade-off analyses, and a COEA.

The CTEA at the CFP stage addresses the relative effectiveness of alternative training programs. That is, given the proposed training program for each alternative materiel approach, is it likely that desired weapon system operational capability can be achieved? The alternative with the highest trainability estimate is, from the point of view of training effectiveness, the best technical alternative.

The CFP identifies those system concepts deemed suitable for demonstration and validation. The concepts represent a single option, alternative systems, or alternative subsystems. The options may include program improvement recommendations for existing systems, purchase of systems from other services or other countries, or new development. The CTEA methodology must deal with all of these contingencies.

Training effectiveness analysis at the CFP stage must consider the probability of training success given current knowledge concerning the efficacy of various training methods for various types of tasks. The CTEA should appraise the probable effectiveness of the training programs proposed for alternative system concepts, identify the strengths and weaknesses of the programs, and supply cost information for comparisons.

Data available include the background information for the CFP: the MENS, Organizational and Operational Concepts, CAP, QQPRI, BOIP, LOA, and input on operational costs and effectiveness for the COEA. The data may include results of research on issues, front-end analysis of prototypes, and an update of system functional requirements. The TASA may be updated, and high-risk tasks may be defined. Required output from the CTEA includes information on the cost and trainability of alternative systems to support the selection of the best technical approach and recommendations of ways to enhance training effectiveness of selected system alternatives.

In the Conceptual phase, two CTEA have been recommended. The first precedes the LOA and provides initial estimates of costs and effectiveness of training based on very rough task statements and personnel estimates. The second uses the information compiled for the LOA and additional information prepared for the CFP. These CTEA are required in the ideal case. In reality personnel and training considerations lag behind hardware development. Thus, task and training data

may not be updated between the LOA and CFP and as a result there may be no new data for the second CTEA. This discussion, however, presents the ideal case since the goal is to provide tools to perform the CTEA as they should be done.

B. Demonstration and Validation Phase

A positive Milestone I decision allows the Army to proceed with the Demonstration and Validation phase. This phase consists of the steps needed to resolve conflicts identified during the Conceptual phase, verify preliminary designs and engineering, accomplish necessary planning, fully analyze trade-off proposals, and prepare the contracts required for full-scale development. This phase includes the use of developmental prototypes in development and operational tests (DT and OT).

Advanced development is conducted by one or more contractors. Personnel constraints determined in the Conceptual phase are a required part of the contracts. The goal of including these constraints is to develop hardware that average soldiers can operate and maintain. The contractors are required to provide a Task and Skill Analysis (TASA) for each operator and maintainer.

The system proponents determine critical tasks from the contractor's TASA. The proponents also evaluate training and training device requirements and estimate whether the operators and maintainers will require new military occupational specialities (MOS), new additional skill identifier (ASI), or modification of existing MOS or ASI.

The personnel task and skill evaluation information is used to develop the personnel and training factors and criteria for DT/OT I, including the skill requirements, mental and physical demands, behaviors, high risk tasks, needs for training development and training materials, and human resource development.

The results of DT/OT I are used to update the Outline Individual and Collective Training Plan (OICTP), Provisional Qualitative and Quantitative Personnel Requirements Information (PQQPRI), initial unit structures, and tentative Basis of Issue Plan (BOIPT). Update of the training support plan includes descriptions of training devices, training methods and media, training extension courses, soldiers' manuals and trainer's guides, field manuals, job performance aids, and other performance guides.

The results of DT/OT I are also analyzed to determine logistic support problems and to assess total life cycle costs. The integrated logistic support (ILS) requirements are revised and alternative logistic support concepts are examined. The estimates of life cycle costs for each alternative system and the resource requirements of the preferred alternative are presented in annexes to the Decision Coordinating Paper (DCP) prepared for ASARC/DSARC II.

One of the documents that supports the DCP, the integrated program summary contains manpower and training implications. The manpower implications cover trade-offs among hardware designs, differences in manpower for old and new systems, manpower sources, new occupations, job task identification, and planned tests and evaluations to verify the manpower estimates. The training implications cover plans for reaching and sustaining the required operator and maintainer proficiency, plans for formal, on-the-job, and unit training, number of personnel to be trained, training costs, and training requirement summaries by fiscal year.

The TRADOC proponent develops the Required Operational Capability (ROC) or Letter Requirements (LR) that include personnel considerations believed to have impact on further development of the materiel system and personnel support. These considerations include training and training device requirements, personnel interface with existing and proposed equipment, system safety, and human engineering factors.

The Acquisition Plan, prepared by DARCOM in this phase, covers such personnel and training requirements as new skills, individual and crew training requirements, training devices, training facilities, and technical documentation.

Personnel estimates are used to develop the Initial Recruiting and Training Plan which indicates personnel and training activities that must precede deployment.

The DCP and other documents are reviewed in ASARC/DSARC II upon completing advanced development.

CTEA Implications

Two CTEA are recommended during the Demonstration and Validation phase, both following DT/OT I and before the ROC. The second is a revision based on information gathered for the PQQPRI.

During DT/OT I prototype systems are demonstrated to show that all technical risks have been minimized and that a working prototype exists. Prior to DT/OT I the training program for high-risk tasks is used to train the test participants. If it is not used or is used so that insufficient data can be derived about effectiveness (e.g., special troops used, no control over training, etc.) then this CTEA resembles a CTEA in the Conceptual phase. If field data do exist, however, the CTEA serves as an analysis of the training programs to verify estimates of trainability based on the effectiveness of the training. Estimates of system effectiveness degradation caused by training problems are also identified.

The COEA in this phase is designed to support the ROC by assessing the attainability of operational effectiveness for the alternative system designs. The CTEA has that function but in addition diagnoses and prescribes training. It uses the lessons learned during DT/OT I to revise projections of training programs, training device requirements, and the OICTP.

The issues addressed at this phase involve the high risk tasks and more detail about personnel and training:

- What are the relative merits of the alternative system approaches to training on the high-risk tasks?
- What is the estimated frequency of training needed to maintain proficiency on the high-risk tasks?
- What devices are needed to support institutional and unit training on high-risk tasks?

- o What are the system training support requirements and associated costs?

- o What hardware/training trade-offs are required to reduce training difficulties?

- o What is the impact on current training and evaluation literature?

- o What are the test and analysis requirements for the engineering development phase?

Ideally, input data from DT/OT I indicate operator and maintainer performance on prototype systems after training and include performance errors, problems in the training programs, time to train, and training program costs. Outputs of the CTEA, given those input data, include the training program strengths and weaknesses, recommendations for improvements, and an update of the cost and trainability estimates.

The second CTEA recommended in the demonstration and validation phase follows the PQQPRI and precedes the ROC. Personnel requirements are revised after DT/OT I and the requirements document is staffed through appropriate Army headquarters. The CTEA at this point considers the test results plus training program revisions made as a result of DT/OT I. The ROC that it supports through the COEA, is the final statement of the system capability the military wishes to acquire. The COEA states the best cost estimate and reaffirms the force effectiveness to be achieved given the DT/OT I results.

The CTEA should provide the training requirements data that form part of the ROC. It should address those issues resolved by test data and provide a final assessment of the trainability of the system concept. It should also provide specific training program goals to be met in the final system. The goals include statements of program elements (e.g., simulator design characteristics, media) as well as statements of the desired levels of training effectiveness (e.g., transfer of training, minimum acceptable levels of post-training skill retention).

In addition to information in the PQQPRI, data available to be used in the CTEA incude DT/OT I data and revisions to training programs. Outputs are training requirements to ensure effective training (for the ROC) and assessments of training program effectiveness.

The second CTEA in the Demonstration and Validation phase is a direct update of the preceding CTEA. The analyst needs only to alter input to the CTEA model that represents revision in training programs after DT/OT I.

C. Full-Scale Engineering Development Phase

During the Full-Scale Engineering Development phase a system, with all items necessary for its support, is fully developed and engineered, fabricated, tested (DT/OT II), and initially type-classified. Concurrently, non-materiel aspects required to field an integrated system are refined and finalized.

DT II evaluates the technical capability of the materiel and support systems including personnel and training requirements. DT II results are used in the decision to initiate full production.

OT II tests the engineering prototype to estimate its operational effectiveness and suitability in a realistic military environment. OT II is designed to employ personnel of the MOS required by the system and to test the technical manuals, training devices, other training material, personnel requirements, and support concept. Instructors trained by the contractor train operators and support personnel for OT II using the training programs developed for the system.

LCSMM documents are revised using the test results. The training proponent determines the changes in the Army Training and Evaluation Program (ARTEP) for the new system. Also, the trainer drafts field manuals containing doctrine, organizational material, and training evaluations.

The proposed system, with prototypes, is analyzed to determine enhancements in reliability, maintainability, support concepts, and logistics. The logistic support analysis contains qualitative and quantitative requirements for support and test equipment, personnel, training, and facilities. The logistic support information is issued in equipment-oriented publications such as technical manuals. Proponent service schools coordinate logistic support analysis records (LSAR) summary sheets, training and personnel doctrine, draft equipment publications, and organizational structures.

Documents revised on the basis of DT/OT II results are the training plan, the Basis of Issue Plan - Complete (BOIPC), and QQPRI. Considerations at the stage of the final QQPRI are:

- Sufficiency of training to provide required proficiency.
- Appropriate MOS and ASI.
- Inclusion of all system components and subcomponents in the QQPRI documentation.
- Adequate number of trained personnel to support the system.

At Milestone III a draft decision coordinating paper (DCP) indicates the status of the system after DT/OT II and refinements of requirements. The DCP includes the Integrated Personnel Support (IPS) annex that summarizes the implementation plan for the acquisition cycle of the system. It covers changes in manpower estimates from Milestone II, effects on manpower of reliability and maintainability levels, shortfalls in meeting manpower requirements, new occupations not yet approved and programmed, and future plans for evaluating manpower requirements. The IPS also presents summaries of formal training requirements by fiscal year and occupation, and plans for the following: attaining and maintaining proficiency required to operate and maintain the system, additional resources required to train the initial set of personnel, training reserve components, and validation of proficiency and performance.

ASARC/DSARC III authorizes full-scale development or limited production of major systems. The item is type-classified as standard if all critical issues were resolved in development and operational testing. Limited production is directed if further testing is necessary.

CTEA Implications

The CTEA in the Full-Scale Engineering Development phase is recommended after DT/OT II and preceding documentation for ASARC/DSARC III. This CTEA assesses training costs to update earlier cost estimates, this time based on experience with total training requirements. In addition, it evaluates the match between training requirements and performance. It is also diagnostic and prescriptive to improve weak training programs.

The issues to be addressed are:

- How effective was the training program in teaching the required tasks?

- Which tasks were not performed adequately during OT II because of poorly designed hardware, poorly designed training, insufficient training, or improper personnel selection?

- What are the impacts of training related deficiencies on operational effectiveness?

- What additional training resources are required to attain the system performance objectives?

- What are the requirements for additional training development and testing prior to full production?

Data input for the CTEA at this stage are from DT/OT II, and the output is the CTEA assessment of the training package. This CTEA provides information for the COEA conducted in preparation for ASARC/DSARC III.

D. Production and Deployment Phase

During Production and Deployment equipment is procured and distributed, operational units are trained, and logistics support is provided. Acquiring and training the personnel demands that the final MOS decision be rendered and the manpower secured, the TOE be approved, personnel requirements and training schedule, new equipment training, including technical documentation, be completed, and the ICTP be approved. Training of personnel needs to be started in sufficient time to support the new system in the field. Resident training is based on revisions of training plans. It requires the training equipment, devices, and other training materials.

Unit training begins when the units receive the system and it must be completed to achieve the initial operational capability. The training is guided by the ARTEP to include critical tasks for the system's wartime mission and is conducted by the cadre who received new equipment training. To achieve operational readiness the operator and maintenance personnel in the unit need to be fully trained. When the unit has the capability to perform the mission the goal of initial operational capability is achieved.

The Army LCSMM allows the possibility that a Milestone III decision authorizes limited production with a follow-on review for full production and deployment. Thus, the Army has procedures to review the system at a later date,

ASARC IIIA and DSARC IIIA. Reviews beyond DSARC III require individual consideration and the reviews vary with the situation.

DT III is conducted on initial production-run items to verify that the items comply with specifications. DT III determines if transition from an engineering prototype to production succeeded.

OT III is conducted on initial production-run items to estimate their operational suitability. The test covers tactics, training, supportability, and organization.

The final QQPRI is prepared eighteen months prior to deployment. It reflects all changes in design and organization and the results of the DT and OT. It supports the final MOS decision.

BOIP II describes the TOE organization; support equipment for the system, where and how much will be deployed, and the personnel implications. The BOIP is used to justify the distribution of the system until the new TOE and TDA are prepared.

The acquisition plan (AP) records program decisions and analyses of technical options and life cycle costs for development, testing, production, training support, and logistic support of the system incorporating the DT and OT results.

The Decision Coordinating Paper (DCP) at the IIIA stage contains information for the optimum production quantities of the system that are consistent with readiness and modernization. The annexes, including the Integrated Program Summary (IPS) are prepared for the ASARC and DSARC. This IPS contains all updated information from tests and experience including changes in manpower and training requirements. The resources funding profile provides the costs of operation and maintenance, personnel, and support for each alternative.

CTEA Implications

Given DT/OT III data, the final CTEA, conducted to update estimates, supplies information for ASARC/DSARC IIIA.

E. Constraints on CTEA Methods

Constraints on CTEA methods derive from the location of the CTEA within the LCSMM, the availability and quality of data, the background, skills, and numbers of personnel available to perform CTEA, and the length of the timeframe within which a CTEA must be performed.

1. CTEA Location. The principal constraints imposed by virtue of CTEA location arise from the absence of empirical effectiveness data on new system tasks before DT/OT I. Tasks of other (fielded) systems may be used to estimate the effectiveness of the training of the tasks of the developing system, but this approach lacks the power to discriminate among training program alternatives that may be obtained through empirical effectiveness data for the new system. Thus, CTEA performed before DT/OT I must have methods for estimating effectiveness. If they are performed before training program alternatives have

been described, they must also have methods for predicting training program alternatives. Since the prediction of training program alternatives usually requires some sort of a task list, the CTEA must have methods for generating task lists if none are available. After DT/OT I the empirical effectiveness data situation changes. Because the concern of DT/OT I is the demonstration of the validity of alternative materiel concepts, there will likely be no training program and thus no comparative effectiveness data. Thus, even after the Demonstration and Validation phase has begun, the CTEA must have the methods of the earlier Conceptual phase CTEA. After DT/OT II there still may not be enough empirical effectiveness data to answer questions; it may be necessary, for example, to consider a training program alternative not predicted in advance of DT/OT II and therefore not tested. Thus, even after DT/OT II CTEA may require the methods of the earlier concept phase CTEA. Variability in CTEA location or timing results from variability from one acquisition program to another. Data other than task lists, training program alternatives, and effectiveness data are also available at different phases and events of the LCSMM.

2. Availability and Quality of Data. Because any particular acquisition program can be expected to conform to LCSMM only in an approximate way, it cannot be expected to consistently yield to CTEA the data implied by the LCSMM. Thus, while the LCSMM as described by Rhode et al. (1980) yields Organizational and Operational Concepts in time to provide input to a CTEA located to provide input to the CFP, an actual acquisition program may not yield such information until much later. Likewise, an actual acquisition may not even yield such fundamental CTEA input data as task lists until very late in the acquisition. (At least one such situation has occurred.) When data identified or implied by the LCSMM are available at the times indicated by the LCSMM, they may not be complete or may otherwise represent an inadequate quality. Task lists, for example, may be only for maintenance tasks, requiring the CTEA to have methods for the generation of operator task lists. Task lists may be grossly in error, making it necessary for the CTEA to proceed as if there were no task lists at all.

The essential point of constraints arising from the way in which actual acquisition programs are implemented is that the selection or development of CTEA methods is driven essentially by the available input data.

3. Available Personnel. In the course of normal career assignments, senior enlisted personnel, warrant officers, and officers can all be expected to be tasked with the conduct of CTEA. Personnel available for CTEA must therefore be expected to vary a great deal in background and skills. CTEA methods vary in complexity, required expertise, and difficulty. Some are not complex methods that require considerable expertise in training development for successful application. Others require less expertise but are much more complex.

4. Available Time. The time available for the conduct of a CTEA appears to be on the order of about 120 days. The importance of this constraint would to some extent vary with the number of persons available to perform a CTEA, but the usual CTEA staff seems to consist of about two or three. Some CTEA methods may not be consistent with such constraints. The use of an analogous task, for example, is not complex and does not require a great deal of expertise, but because analogous tasks must be located (perhaps through an extensive search of the documentation of fielded systems), it could require more time than is available. Methods available for the conduct of CTEA must also recognize these constraints.

Because of the nature of constraints acting on CTEA, the process methods that any particular CTEA must make use of cannot be predicted on the basis of the location of the CTEA within the LCSMM. Rather, methods must be tentatively selected on the basis of the situation which a particular CTEA encounters with regard to available data. Tentative selections must be further constrained by considerations of available personnel and time limitations.

F. Summary

To the extent that training produces or maintains mission-oriented skills required system effectiveness is obtained. Tasks essential to mission accomplishment with alternative designs or concepts vary in the difficulty with which they are trained, so overall operational effectiveness also varies. An accurate determination of operational effectiveness must be based on the maximum proficiency obtained with each design and the cost of training necessary to achieve that proficiency. The CTEA should provide that information. The CTEA methodology is iterative and is updated as new information becomes available. The CTEA results are increasingly detailed and accurate as the life cycle of the system progresses.

SECTION III

COST AND TRAINING EFFECTIVENESS ANALYSIS METHODS

The literature of training development describes a number of methods that are either CTEA methods per se or applicable to some aspects or processes of CTEA in the LCSMM. While some of these methods have been developed for application to developing systems, others assume fielded systems, and none embraces all of the requirements of CTEA in the LCSMM. A purpose of this research was to organize the varieties of CTEA and related methods so that the analytical needs of each CTEA location in the LCSMM could be met. What was envisioned was the synthesis of a family of CTEA methods applicable to the LCSMM rather than the development of a new method which would meet all needs.

To establish a basis for the synthesis of CTEA methods suitable for the various stages of the LCSMM, all seemingly relevant CTEA methods described in the current literature have been examined. This examination of existing methods has attempted to answer three principal questions:

- To what extent does the analysis described represent a true CTEA method in the sense that given precisely defined inputs another analyst could derive precisely defined effectiveness and cost output?
- To what extent does the analysis, or the purported CTEA method, embody processes usable within the contexts of a variety of CTEA designs?
- For which stage of the LCSMM, if any, would the purported method or its embodied processes be most suitable?

Each method was examined in light of the needs of CTEA in the Army LCSMM regardless of its purported purposes or established uses. The focus was on the details of processes rather than the overall conceptual scheme. The summaries of methods thus developed established the basis for the effort to synthesize a family of CTEA methods.

Since the DOD directives containing guidance on the LCSMM were issued, many studies have been published documenting from various perspectives the costs and effectiveness of training systems for developing and operational systems. They have been variously approached as cost effectiveness analyses (C/E), cost and operational effectiveness analyses (COEA), cost and training effectiveness analyses (CTEA), and weapon system training effectiveness analyses (WSTEA). These assessments have been performed at different stages of the LCSMM, some fully supported and iterated as required and others given considerably less time or resources.

The summaries of CTEA and related methods that follow represent those that appear most applicable to the CTEA now being conducted as an aspect of the Army's materiel system acquisition processes but by no means do they constitute an exhaustive catalog of methods that might be applied. Jorgensen (1979) has identified some innovative methods and techniques with possible useful applications within training development and CTEA that are not included here. Nor have all

of the methods and approaches summarized below been included in the CTEA Performance Guide since some will require additional study and development (or revision) to make them useful and feasible as CTEA methods.

Most of the following methods and CTEA approaches are listed under commonly used names and acronyms. Formal bibliographic information is included within parentheses.

1. TEEM (Jorgensen and Hoffer, Prediction of Training Programs for Use in Cost Training Effectiveness Analysis, 1978)

The current acquisition policy requires effectiveness comparisons of the training alternatives of developing weapon systems. In the early stages of development, however, these systems have no training programs to serve as a basis of comparison. In the case of truly innovative systems, furthermore, there are no analogous systems with training programs that could provide base cases. A predictive computerized model for CTEA use has thus been developed by Jorgensen and Hoffer (1978). Their Training Efficiency Estimation Model (TEEM), begins with task analysis, proceeds through selection of training media and methods, identifies information content and structure, and generates a cost/effectiveness ratio. Iterations of the model for various training system options produce cost/effectiveness ratios for comparisons of the options.

In TEEM trade-offs are recorded during the generation of an estimated training program. These trade-offs estimate the potential decision cost for the chosen training program compared with an ideal program with no constraints. That is, an ideal, unconstrained program is quantified and compared with a similarly quantified real-world (constrained) training program. This measure provides a standard of comparison for several training programs generated with the same CTEA method and has potential advantages not only for the comparison of alternative programs for a given weapon system but also for comparison across weapon systems.

The measure, the efficiency ratio, represents a value composed of the efficiency score of an estimated program with real world constraints divided by the efficiency score of an idealized program with no constraints. Outputs of this method include a cost-analyzed training program. Input requirements are task list plus sufficient knowledge of the weapon system to permit inferences about the nature of stimuli, responses, and feedback.

The heart of TEEM is a set of variables -- called a "metalanguage" -- used to describe tasks to be learned and the means (media and methods and, perhaps in the future, content and content structure) of learning them. When each variable in the description of the task is matched by the corresponding variable in the descriptions of the training program, an ideal training program is identified. That is, for each stimulus, response, and feedback need presented by the tasks there is a medium-method combination in the training program to meet the need. Because of costs and other constraints such an ideal training program cannot be achieved. Rather, as the result of designing a training program within real-world constraints something less than an ideal program is actually achieved. The difference between the real-world program and the ideal is expressed by the efficiency ratio.

The metalanguage includes three main classes of variables: stimulus, response, and feedback. In addition, there are method (functional context), content, and structure variables. These variables represent relationships between task conditions and requirements and learning media and methods as identified through a thorough review of the training literature (Figure III-1). Matching tasks with media-method combinations through this metalanguage assures that the training program is responsive to research findings regarding the relationships between tasks and media/methods.

TEEM begins with the identification of task information in the form of standard ISD task statements or, if the materiel system has not progressed to the stage that would make these statements available, in the form of gross task lists derived from materiel system descriptions (draft TMs, LSARs, etc.). Once the analyst has identified the tasks, he/she describes the task stimulus, response, and feedback variables. To describe the task stimulus variables, for example, the analyst scans a list of 39 stimulus variables and records those that apply (e.g., audio cues, intensity, channels or sources). To describe the response variables of the task the analyst repeats the process using the list of 16 response variables. Likewise, the list of 17 feedback variables is scanned to describe the task feedback.

Unless a task is trained alone, it is assigned to a group of tasks according to its functional context (training method). Functional context variables apply to groups of tasks that are performed together on the job and are thus trained together. In the case of tasks resulting from a formal ISD process, the relationship of tasks to terminal learning objectives is given in the form of learning hierarchies; in the case of gross task information it may be possible to estimate terminal learning objectives from system scenarios and then to cluster tasks accordingly.

The functional context (training method) is described for clusters or groups of tasks using 13 variables that describe the context in which a task group or cluster is performed and should thus be trained. For example, the task may require individual performance (performed alone). It may be primarily physical (overt bodily actions), unstable (not constant or regular but subject to continued change), and characterized by a physical context of low impact (the physical environment has little effect on the performance of the task) and a psychological environment of low impact (the psychological environment has little effect on performance of the task).

The selection of media (training devices and materials) is accomplished by the TEEM computer program in which training devices and materials have been described using the same variables used to describe the tasks. Media with the highest number of matches with tasks become candidates for selection.

The media selection procedure results in stimulus, response, and feedback media for each task. Since an array of media is not supportable in the real world, the media set for each functional group of tasks is reduced to a supportable number derived from the matches between task descriptions and media descriptions. The ideal, unconstrained training program establishes the base case against which reduced media sets are compared. By definition, the efficiency of this media set is 1.0. All reduced media sets have an efficiency of less than 1.0.

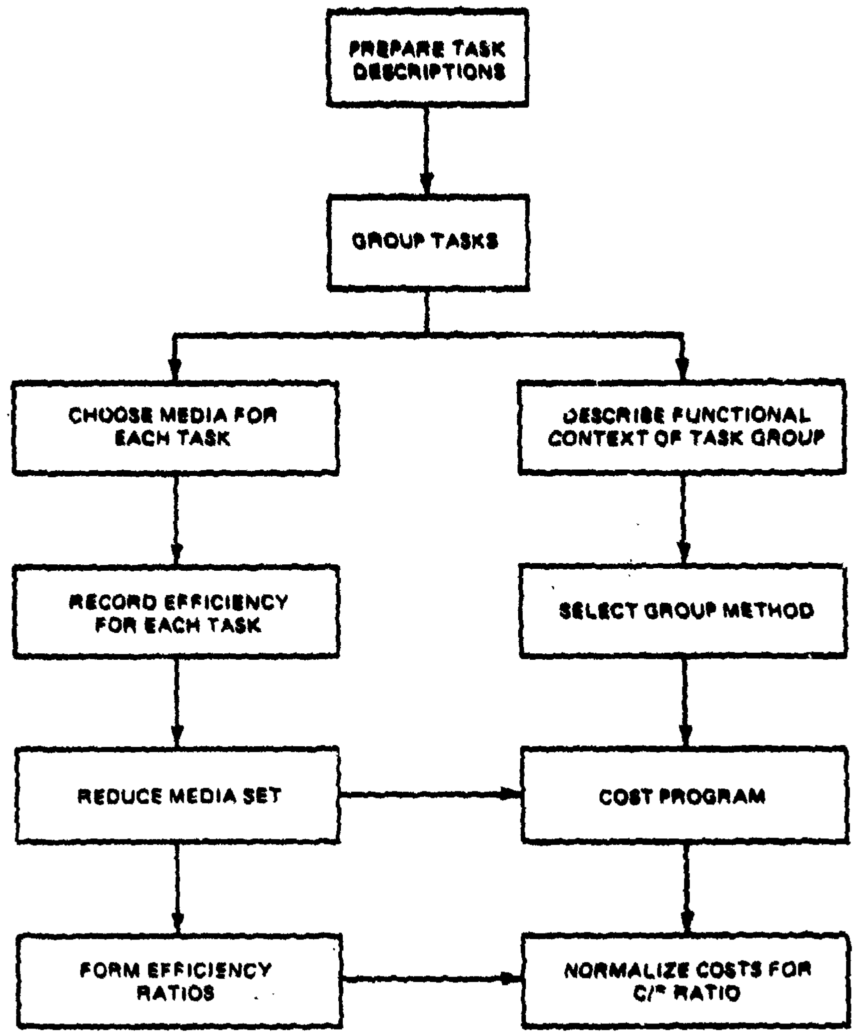

Figure III-1. TEEM Overview
(from Jorgensen and Hoffer, 1978)

The TEEM computer program, the medium with the lowest number of matches across all tasks from the media set in each matrix (that is, the medium least useful for stimulus presentation, receiving responses, and providing feedback). Iteration of the procedure measures the fit of all tasks with all functions and this measure divided by the measure of the ideal, unconstrained case expresses the efficiency of the reduced media set. The medium in each matrix with the lowest number of matches across all tasks is removed from consideration, and the efficiency of the further reduced media set is calculated. Iterations of the procedure continue until all media have been removed.

Efficiency ratios are plotted against the number of the iteration. This plot shows the iteration where the efficiency begins to drop off steeply and the analyst uses it to select a media set that provides the lowest acceptable efficiency (Figure III-2).

The method selection procedure uses functional contexts and their appropriate instruction methods. Selection is based on the number of matches between task and training approach. The method with the highest number of matches with functional context variables is selected for each task group.

Costs are determined by describing media and methods in terms of 37 cost variables and the cost data are analyzed by the computer program. Outputs are program costs.

Once costs have been obtained, a decision metric, a cost/effectiveness ratio, is obtained by dividing the cost by the efficiency value. The analyst chooses alternative methods, calculates their efficiency values and costs, and obtains their cost/effectiveness ratios. The analyst could recommend the method with the lowest cost effectiveness ratio (the lowest cost for at least an acceptable efficiency), or he might recommend a method with a slightly higher cost effectiveness ratio to obtain a large increase in efficiency at a higher cost.

2. Training Consonance Analysis (Hawley and Thomason, Development of an Air Defense Cost and Training Effectiveness Analysis Methodology, 2 vol., 1978)

Hawley and Thomason's Training Consonance Analysis (TCA) technique is a modification of TEEM that compares training alternatives on the basis of task descriptions and the methods and media employed to train the tasks. TCA uses the same variables as TEEM to describe tasks and media-method combinations. Unlike TEEM, TCA uses the descriptions to indicate how close the media-method combinations come to the task description; that is, TCA yields an indication of the consonance of the task descriptions and the training programs. Hawley and Thomason further modified TEEM by adding the diagnostic concepts "training deficiency," "training excess," and "training redundancy."

- Training deficiency: A variable in the task description does not occur in the training description.

- Training excess: A variable in the training description does not occur in the task description.

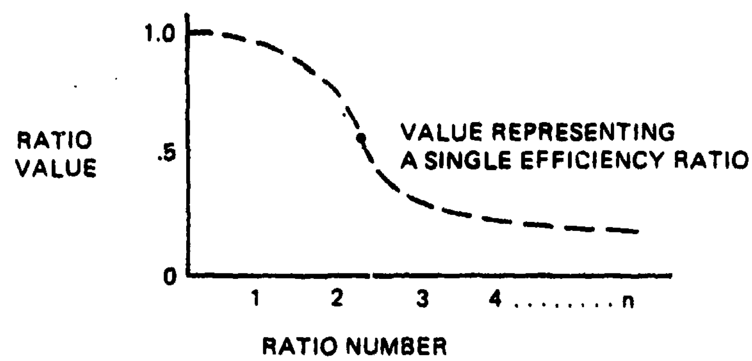

Figure III-2. Plot of Efficiency Ratios (the loss function) (from Jorgensen and Hoffer, 1978)

- Training redundancy: A variable in the training description which is redundant. This occurs only if two or more training media and/or methodologies are combined in the training description. The variables common to two or more media/methodologies are redundant.

These diagnostics explain the differences in the efficiencies of alternative training programs. The smaller the number of excesses and redundancies, the more efficient a training program is in media and methods.

TCA describes each task according to the 85 psychological variables on which TEEM is based. The task descriptions are coded on data cards for computer processing. The next step is the identification of the media and methods for training each task perhaps from a training prescription such as TEEM, TECEP, and TDDA. Information in the following four categories is needed:

- The stimulus medium (through which information about the task is presented to the student).

- The response medium (through which the student demonstrates what he has learned about the task on about any other information presented through the stimulus medium).

- The feedback medium (through which the student receives information about the correctness of his response).

- The training method (which describes the pattern of interactions among students, instruction, and media).

The TCA program analyzes the media and method matrices to compare task descriptions, variable by variable, with the descriptions of media and methods. When a variable is present in both the task description and the description of the medium-method combination used to train the task, a training consonance is scored. Otherwise, training deficiency, excess, or redundancy is scored. The training consonance ratio is given by the total number of training consonances scored for the task over the total number of variables in the task description. If 36 training consonances are scored and 39 variables are in the task description, then the ratio for that task is .923.

The TCA program aggregates output over groups of tasks and over all tasks. The output, therefore, may be used to evaluate groups of tasks (which correspond to modules of instruction) as well as to evaluate individual tasks or the entire program. The outputs of the TCA are summarized as follows:

- Outputs are given for each task, for each group of tasks, and for all tasks.

- Outputs for each task include training consonance ratios training deficiencies, training excesses, and training redundancies (see definitions of deficiencies, excesses, and redundancies above).

- Outputs for task groups and all tasks include the total number of training consonances, the total number of variables in task descriptions, and the training consonance ratio.

Training consonance ratios and diagnostics provide a basis for recommendation of a training program and for improving the program.

3. CHRT (Goclowski *et al.*, *Integration and Application of Human Resource Technologies in Weapon System Design: Coordination of Five Human Resource Technologies*, Vol. 1, March 1978; *Process for the Coordinated Application of Five Human Resource Technologies*, Vol. 2, March 1978; and *Consolidated Data Base Specification*, May, 1978)

The Advanced Systems Division of the Air Force Human Resources Laboratory combined five technologies in the weapon system acquisition process: maintenance manpower modeling, instructional systems development, job guide development, system ownership costing, and human resources in design trade-offs. All five are applied individually during the materiel acquisition process and have data requirements in common. Therefore, one objective was to integrate and apply the technologies to form a coordinated human resources technology (CHRT).

A second objective was to design a consolidated data base (CDB) to support CHRT application. The CDB establishes a common source of information for human resource technologies early in the acquisition process. A CDB is established for each weapon system in the acquisition process and it grows as the system develops. Each of the five coordinated human resource technologies draws on the CDB for input, and many of the outputs go back into the CDB. Thus, one data base contains information relevant to reliability, maintainability, maintenance manpower, operations manpower, training, job guides, and system ownership costs. It supports human resource planning during the acquisition process and continues to support operational and logistic planning after the system is deployed.

It is useful to examine the five human resource technologies separately. Maintenance Manpower Modeling (MMM) is a method for estimating the manpower required to maintain a new system and the effects of certain trade-offs. Maintenance action networks are developed to describe necessary maintenance; these consist of sequences of maintenance events required to complete the action. They describe the probability of occurrence, time to complete, and support equipment and personnel needed for each maintenance event. The descriptive data are derived from the analysis of comparable existing systems. The maintenance action networks are paired with mission scenarios to simulate the maintenance of the system under mission conditions. The simulation predicts maintenance manpower requirements.

Instructional System Development (ISD) within CHRT differs from ISD in other contexts in that it is coordinated with other human resource technologies and draws its data from a base common to these technologies. It results in training concepts during the concept phase of system acquisition, a training plan during the validation phase, and a fully developed training program during the full-scale development phase.

Job Guide Development (JGD) results in products that may substitute for or reduce the need for training. JGD at present appears to be concerned with maintenance tasks although guides for operatinonal tasks are consistent with the JGD concept.

While a large component of Life Cycle Costs (LCC) is the acquisition cost (research and development and procurement), a comparable component is the cost of operating and supporting a system once it has been procured. This second component, system ownership cost (SOC) includes human resource considerations such as personnel requirements for operations, support, and training. Every decision made as a result of MMM, ISD, and JGD has an associated cost, and it is through SOC that such costs are assimilated into the LCC.

Human Resources in Design Trade-Offs (HRDT) identifies points in systems development where the selection of alternatives has a large impact on human resources. The HRDT Design Option Decision Tree maps selections of systems alternatives that have occurred or will occur. The decision tree identifies trade-offs, develops data, and studies to conduct.

CHRT integrates MMM, ISD, JGD, SOC, and HRDT. The individual technologies retain their distinct characteristics but they interact through a common pool of information, the CDB. A human resource trade-off identified by HRDT, for example, is reflected in ISD, JGD, and SOC. Conversely, an excessive cost flagged by SOC or a support problem identified by MMM will lead to a revision in ISD.

CHRT consists of four activities: (1) consolidated data base development, (2) the integrated requirements and task analysis, (3) ISD/JGD product development, and (4) the impact analysis. The CDB is the key to the consolidation of the five technologies. The CDB consists of all data that the five technologies develop separately, but through consolidation it eliminates redundancy and achieves efficiency and effectiveness in the use of data (Figure III-3).

The CDB begins with historical data and assimilates updated data as they are developed. It includes data on a reference system (an actual or conceptual systems), one or more alternative baseline systems, and current systems.

The integrated requirements and tasks analysis (IRTA) combines ISD and JGD analyses for maintenance and operations with maintenance manpower modeling (MMM). IRTA is predictive during the conceptual and validation phases, but it becomes product oriented during the full-scale development phase. It determines manpower, ISD, and JGD requirements as well as the detailed task analyses needed to develop ISD and JGD products. It is an iterative process, drawing heavily at first on historical data (comparability analyses, maintenance records, information on existing courses, characteristics of available personnel, etc.) and then assimilating empirical data as the system evolves.

The ISD and JGD product development activity is also iterative. As the data become more detailed it produces the training and technical data (job guide) concepts, the ISD and JGD plan, and the ISD and JGD program.

Impact analysis, the final CHRT activity, is the investigation of the impacts on human resource costs of a variety of system alternatives. CHRT assigns human resource and other systems ownership costs to system design, maintenance, operations, and support alternatives so that these costs may be fully considered during the early and critical acquisition decisions.

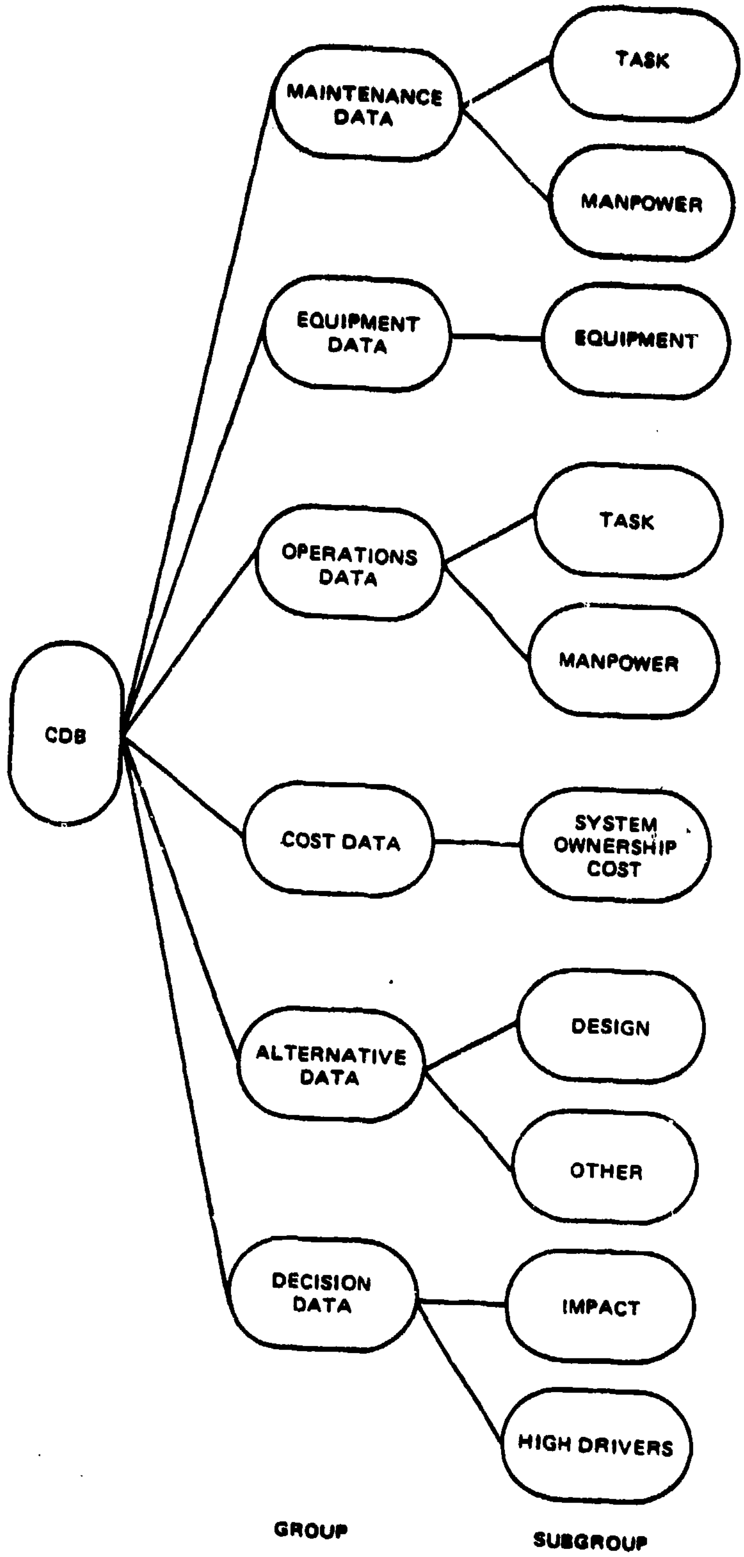

Figure III-3. CDB Structure

4. TECEP (Braby et al., A Technique for Choosing Cost-Effective Instructional Delivery Systems, TAEG Report No. 16, 1975)

Of all available analytical methods with potential applications to CTEA, the Training Effectiveness, Cost Effectiveness Prediction (TECEP) technique appears to be the most consistent with current ISD procedures: TECEP and ISD employ the same learning guidelines and algorithms. TECEP is used during the conceptual phase for training program development.

The TECEP technique begins with a list of training objectives, classifies those objectives according to the type of learning algorithm required, selects alternative media systems to support those algorithms, estimates the cost of each alternative delivery system, and identifies a cost-effective instructional delivery system. The technique is simple though its developers caution that it is intended for use by experienced training system designers.

TECEP is applied within training systems development (Figure III-4). Once training objectives have been analytically derived TECEP identifies and costs instructional delivery systems. The three-step procedure is given in Figure III-5, and the reference materials needed to implement the procedure are shown in Figure III-6.

Each training objective is matched with one of twelve learning algorithms. The matching is through a comparison of the task with the various algorithms in terms of action verbs, behavioral attributes, and examples of objectives (Figure III-7). Once tasks and objectives have been classified and grouped according to the learning algorithms a table is used to select delivery systems for each group of tasks and objectives. Each system is then analyzed for cost-effectiveness comparisons.

5. The BDM/CARAF Method (Cost and Training Effectiveness Analysis Handbook for Action Officers, 1976)

The BDM Service Company Combined Arms Research and Analysis Facility (CARAF) guide for CTEA outlines the process rather than providing a procedure or method whereby inputs lead to precisely defined outputs. The guide suggests a number of measures appropriate to the types of training systems identified. It also requires an interval scale but does not indicate how to quantify on an interval scale.

The BDM guide to CTEA describes eight procedures for each of eight types of training systems. The procedures are quite similar, however, and differ only in measures of training effectiveness. The eight types of training systems are: large group war games simulator, individualized or small group lessons, small group tactical maneuver and deployment game, hands-on performance aid, large weapon system practice firing adapter, small group combat engagement simulator, trouble-shooting trainer simulator, and small weapon system practice firing adapter. Suggested measures of training effectiveness for large group war games simulators are: rates of movement, rates of attrition, combat power ratios, casualties, ammunition usage, batties won, missions accomplished, and others. Measures of training effectiveness are suggested for each of the eight types of training systems.

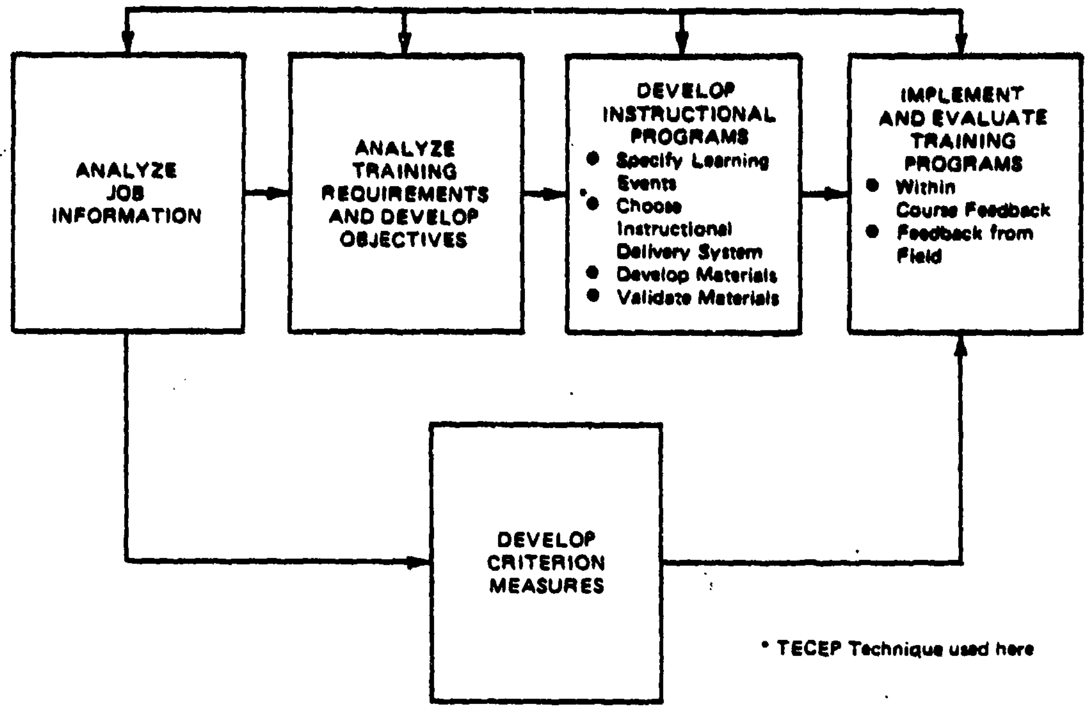

Figure III-4. Training System Development Model
(from TAEG Report No. 16)

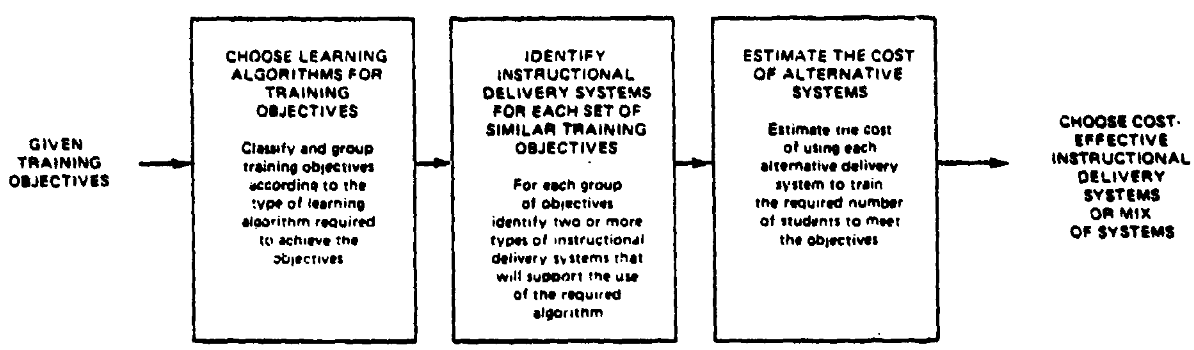

Figure III-5. Process Flow in the TECEP Technique
(from TAEG Report No. 16)

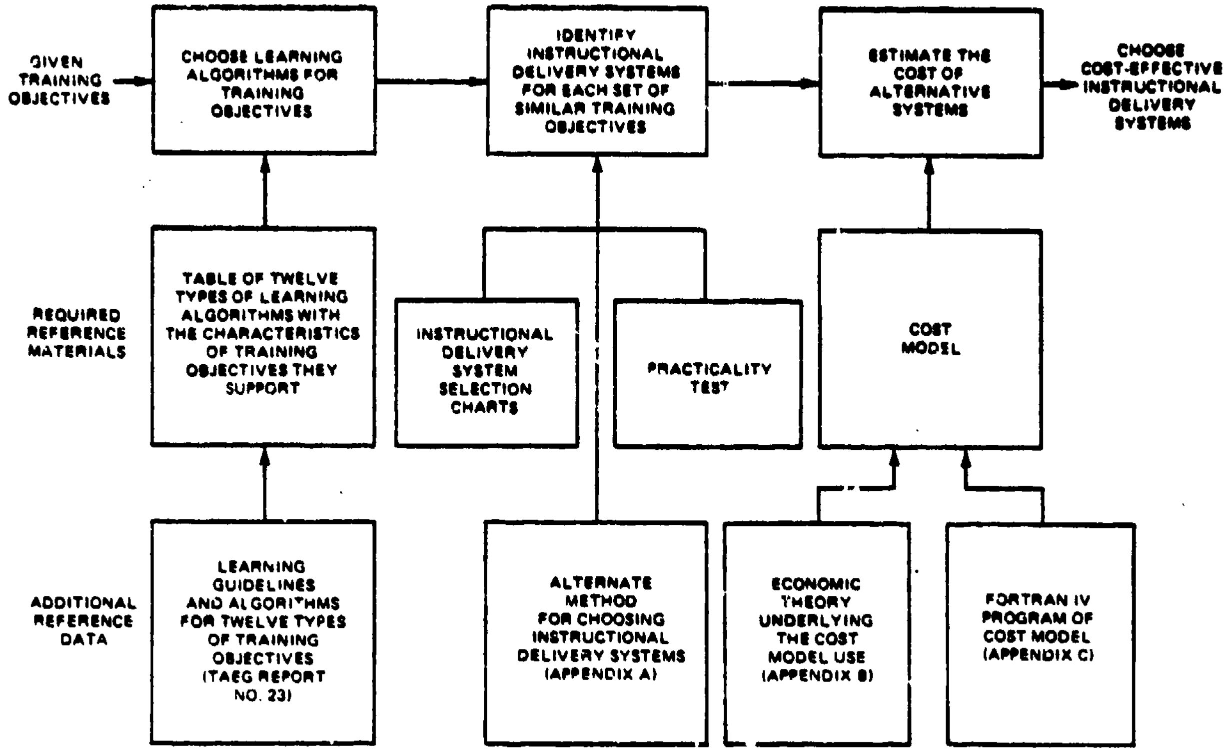

Figure III-6. Reference Materials Supporting the TECEP Process Flow (from TAEG Report No. 16)

	CHARACTERISTICS OF TRAINING OBJECTIVES THAT CAN BE ACHIEVED WITH SPECIFIC ALGORITHMS		
NAMES OF LEARNING ALGORITHMS	ACTION VERBS	BEHAVIORAL ATTRIBUTES	EXAMPLES
9. RECALLING PROCEDURES, POSITIONING MOVEMENT	Activate Adjust Align Assemble Calibrate Disassemble Inspect √Operate Service	√1. Concerns the chaining or sequencing of events. √2. Includes both the cognitive and motor aspects of equipment set-up and operating procedures. √3. Procedural check lists are frequently used as job aids.	1. Recalling equipment assembly and disassembly procedures. √2. Recalling the operation and check-out procedures for a piece of equipment (cockpit check lists). √3. Following equipment turn-on procedures-emphasis on motor behavior.

Figure III-7. Sample of Matching Training Objective Characteristics with a Type of Learning Algorithm (from TAEG Report No. 16)

As an illustration of the BDM/CARAF method for CTEA, the procedure for individualized small group lesson delivery system is summarized below. Only steps of some substance have been included, and the distinctions among these have not necessarily been preserved.

After precisely defining the training system under investigation, the analyst chooses the standard measure of effectiveness, which is an aggregate of less comprehensive measures of training effectiveness. In this case such a measure might be a summary index score of effectiveness. Next, the analyst chooses measures with positive or negative relationships to the standard measure of effectiveness. In the case of the standard measure identified above, these might be measured achievement, measured retention, and completion time. In the case of the procedure for small-group tactical maneuver and deployment instructional game, the standard measure of effectiveness might be a platoon leader performance score, while the measure would include missions accomplished, number of losses, and platoon leader evaluations. For each alternative system (including a base case system) data would then be collected for each measure. The scores for each measure are weighted and a total weighted effectiveness score for the base case and each alternative is derived (Table III-1). Using a simple cost model, the analyst estimates the Life Cycle Cost of the base case and each alternative (Table III-2).

Table III-1. Calculation of Total Weighted Effectiveness Scores (E)

	$MOTE_1$	$MOTE_2$	$MOTE_3$	$MOTE_4$	ΣE	
WEIGHTS→*	80	90	85	75		
BASE CASE	29.6	57.6	46.75	42	175.95	← E_B
A_1	25.6	32.4	38.25	33	129.25	← E_{A_1}
A_2	24.8	0	0	0	24.8	← E_{A_2}
A_3						← E_{A_3}

Each training system is compared with others through a cost benefit analysis of the general form:

$$\text{Cost}_{\text{Base Case}} \;\begin{matrix} > \\ < \\ = \end{matrix}\; \text{Cost}_{\text{Alternative}} \times \frac{\text{Effectiveness}_{\text{Base Case}}}{\text{Effectiveness}_{\text{Alternative}}}$$

Table III-2. Cost Model

COST AND TRAINING EFFECTIVENESS ANALYSIS

	THIS	REPLACES
NAME:		
DATE:	/ /	/ /
PAGE:	of	of

PREPARED BY: ______________________

ORGANIZATION: ______________________

	BASE CASE*	A_1*	A_2*	A_3
1. R&D COSTS				
Lesson Development	637,000		3,000,000	
Lesson Revision	733,000		1,000,000	
SUBTOTAL	1,370,000		4,000,000	
2. INVESTMENT COSTS				
Purchase of Lessons				
Purchase of Audio-visual Eqpt.				
SUBTOTAL	4,526,000		8,000,000	
3. OPERATING AND SUPPORT COSTS Lesson Distribution	1,376,000		4,000,000	
Logistical Support	478,000		1,000,000	
Administrative Support	23,642,000		5,000,000	
Instructional Support	10,708,000	50,473,000		
SUBTOTAL	36,204,000	50,473,000	9,000,000	
4. TOTAL LIFE CYCLE COSTS	42,100,000	50,473,000	21,000,000	
5. TOTAL LIFE CYCLE UTILIZATION UNITS	266,500	266,500	266,500	
6. LIFE CYCLE COST PER UNIT	157.97	189.39	78.80	
	↑ C_B	↑ C_{A_1}	↑ C_{A_2}	↑ C_{A_3}

*These data are for illustrative purposes only.

When the two values are equal, the compared systems are equal in cost benefits. When the first term is the smaller value, the base case is better than the alternative. And when the first term is the larger value, the alternative is better than the base case.

6. MODIA (Method of Designing Instructional Alternatives). Reported in 5 volumes by Carpenter-Huffman et al., 1977)

MODIA's developers explicitly characterized it as neutral with regard to effectiveness of training designs. It does, however, reveal the impacts of design decisions and thus encourages designers to consider alternatives. Considerations include implications of the subject matter for training resources and strategies, effects of student characteristics on learning, effects of course management and teaching strategy on learning and resources, and how changes in one course design element influences the others.

The method is useful for comparing well-developed training program alternatives. Because of the level of detail required, however, it does not seem applicable early in the LCSMM. Details required as input include whether the course requires unusually expensive or scarce resources, course content sequencing, maximum and minimum numbers of students, effects of tests on student progress, how each unit of the course will be taught, time required, attrition, and availability and unit cost of resources.

Major output from MODIA includes projection of average and peak student loads, average time to graduation or attrition, student waiting time, percent of time each resource is used, resources required, and the start-up, annual, and five-year costs.

MODIA consists of four elements: a description of options for course design; a user interface; a resource utilization model (RUM), and a cost model. The first describes the choices in the design of courses, the data required to use the systems, and guidelines for making design choices. The second leads the user step by step through a series of decisions that result in a course description. The third simulates operation of the course to identify required resources. The fourth estimates five-year investment and operating costs. The relationships among the four elements of MODIA and the user are illustrated in Figure III-8.

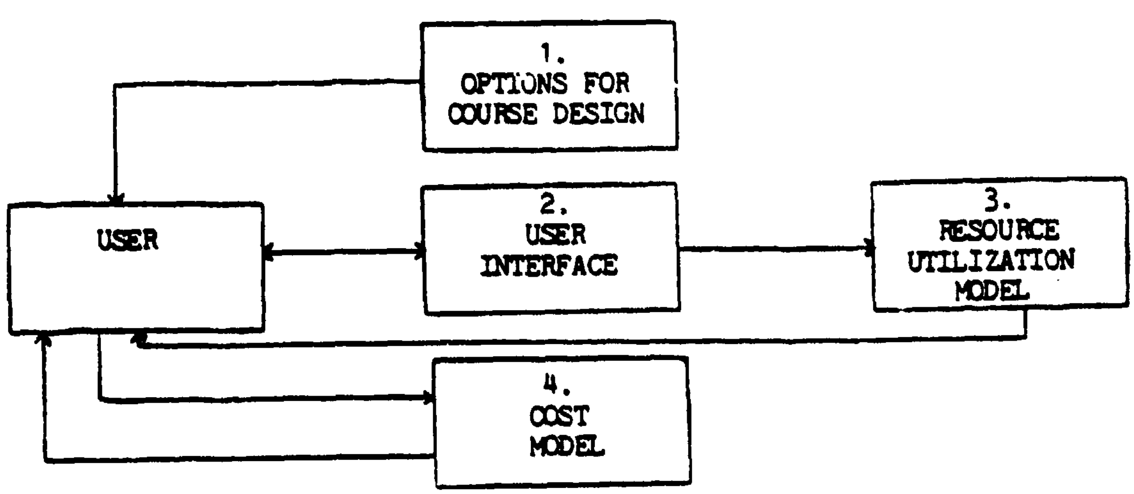

Figure III-8. Relationships Among MODIA Elements and the User

Before attempting to make use of the computer-based elements of MODIA (the user interface, the resource utilization model, and the cost model), the user studies the options for course design then gains access to the user interface (UI). The UI poses a series of questions that lead the user through the design process. It asks where the user wants to begin since some of the design work might have been completed during previous sessions. The UI begins the questions relevant to the phase in which the user wants to begin. The eight sequential phases of the UI are as follows:

- o Select the planning phase.
- o Describe objectives and tests.
- o Describe student population and course diversification.
- o Describe teaching policy.
- o Describe test details.
- o Describe resources.
- o Describe resource constraints.
- o Define resource utilization model (RUM) parameters. (These tell the RUM when to stop the simulation.)

The program transforms the course design for input to RUM, and RUM analyzes the performance of the course by simulating the flow of students through it. Within the processes of RUM, for example, students enter the course at random or at prescribed intervals, progress through a sequence of learning events, use different amounts and types of resources, may be matched with learning events on the basis of their individual characteristics, may be temporarily held up while they wait for resources or for other students, and may fail and then have to repeat all or part of the course. The user probably begins with very brief simulations to determine if bottlenecks or other problems exist. As he/she works out the problems, he/she orders longer and longer simulations to verify that the course is indeed working as desired. Once satisfied with the operation of the course, the user assembles available cost data along with RUM and UI outputs for input to the cost model. The cost model then provides estimates of costs.

7. DAIS/TRAMOD Method (Czuchry <u>et al.</u>, <u>Digital Avionics Information System: Training Requirements Analysis Model User's Guide</u>, 1978)

The Training Requirements Analysis Model (TRAMOD) is one of a group of computerized analytical models that make up a life cycle cost model. It is similar to MODIA in that it is a computerized means for training design, but unlike MODIA it makes design decisions rather than simply revealing the impacts of decisions already made. TRAMOD selects from an input list the tasks to be trained. It generates a training plan consisting of place of training (school or OJT), method of instruction (simulation, performance, lecture, etc.), and media (simulator, mockup, etc.). Finally it determines possible schedules. Task input includes values for a number of parameters: criticality; learning difficulty; frequency; psychomotor level; cognitive level; and estimated time required to accomplish training. In the early stages of design of new equipment, data values are obtained from comparable operational equipment.

TRAMOD considers cost but not effectiveness. Given adequate task data, it would appear to be a valuable CTEA method for comparing training alternatives resulting from various constraints (limits on training time, equipment shortages, etc.). The general process of TRAMOD is illustrated by Figure III-9.

The preparation of the task data base required by TRAMOD is a manual operation of considerable difficulty. The authors of the method suggest that "... the values assigned to the task characteristic parameters should be based on the judgments of engineers and technicians familiar with the equipment upon which the tasks will be performed" (p. 12), but implementation of such a suggestion seems to require a change in the way hardware manufacturers currently perform task analyses. The requirement for such a change constrains successful use of the method.

Once the task data base has been prepared and entered the user interacts on-line with the program by specifying constraints on the selection of tasks to be trained, the generation of the training plan, and the generation of the training program (possible schedules, types and numbers of media required, number of classes, etc.). The user specifies the lowest (threshold) value of a task characteristic parameter that selects a task for training. In the task data base each task is evaluated for criticality, learning difficulty, frequency, psychomotor level, and cognitive level on a scale of 1 to 5. By setting the value for each of these five parameters, the user places constraints on the selection of tasks. The user then specifies which of five algorithms will be used to test the values. One such algorithm, for example, requires each of the characteristics of each task to meet the threshold value set for it while another requires the average of the characteristics to meet the average of threshold values. If the user were to set a threshold value of 3 for each of the five characteristics (criticality, learning difficulty, frequency, psychomotor level, and cognitive level) and were to choose the first algorithm described above to make the test, then the program would select for training a task evaluated as criticality = 5, learning difficulty = 3, frequency = 3, psychomotor level = 4, and cognitive level = 3. If the user were to choose the second algorithm described above both tasks would be selected for training since the average value of the characteristics is at least 3. The user could, in turn, select all five of the algorithms to make the test and then compare the results.

TRAMOD generates blocks of tasks to be trained in the school or on the job. Tasks that must be trained together are assigned to the same block.

Once satisfied with the set of tasks selected for training, the user proceeds to the generation of a training plan by answering a set of questions. The first question concerns how costs and training times are to be determined. The first choice results in direct use of the time and cost data contained in the input data set for each task; the second choice results in computation of time and costs as functions of variations in the levels of the value of tasks characteristics, with the regression coefficients being provided by the user; the third choice results in computation of time and costs on the basis of regression coefficients stored in the computer (TRAMOD). The second question concerns how students are to be assigned to school and OJT. The options are termed "mixed" and "non-mixed." In the "mixed" option (students are trained on some task blocks in the school and some OJT) TRAMOD distributes task blocks between the school and OJT on the basis of minimal cost within time constraints. In the

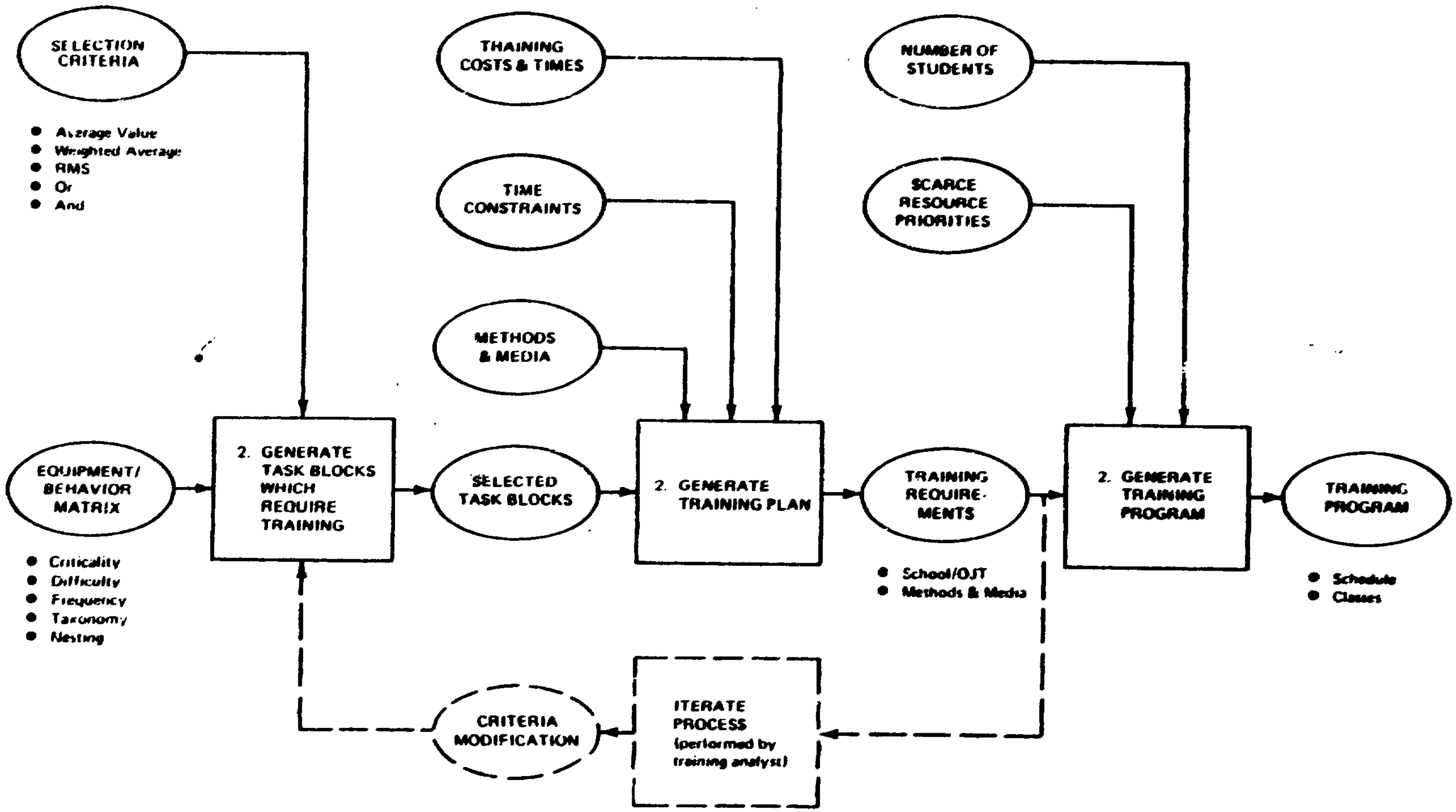

Figure III-9. Training Requirements Analysis Model (from Czuchry, et al., 1978)

"non-mixed" option (student is trained in the school or OJT but not both) TRAMOD either calculates the split of students between the school and OJT or separately tests school training and OJT against given time and cost constraints, depending on choices made by the user.

The next questions ask how training objectives are derived from the task data and how media and methods are assigned to training objectives. The user can allow TRAMOD to make these decisions on the basis of information stored in the computer or make certain alterations in the way the matches are to be made. TRAMOD, for example, matches a task group evaluated as psychomotor level = 4 and cognitive level = 2 with Training Objective 3, Understanding Principles and Relationships. For this training objective it then assigns simulation as a method and simulator as medium to school training, and performance (hands-on) training as a method and mock-up as media to OJT. The user can decide to match cognitive level = 2 with Training Objective 4, Learning Procedural Sequence. Further, he can decide that the methods/media will be discussions with transparencies in the school and simulation with simulators in OJT.

To generate the training program the user sets minimum and maximum class size for school training, identifies the task characteristics that serve as the criteria for ordering tasks for training, and indicate which media are optimally scheduled because of scarcity. TRAMOD prints schedules showing the order in which tasks are to be trained, whether a task is to be trained in the school or in OJT, days required to train each task, the cost of training each task, the method for each task, and the medium for each.

After considering the results of the decisions he/she has made, the user can rerun the program, alter his decisions, and compare the new results with former results.

8. TDDA (Pieper <u>et al.</u>, <u>Training Developers Decision Dialogue for Optimizing Performance-Based Training in Machine-Ascendant MOS</u>, 1978; and <u>Tryout of a Training Developers Decision Aid for Optimizing Performance-Based Training in Machine-Ascendant MOS</u>, 1979)

The TDDA is similar to TECEP with one new element added, Response Acceptance Mechanisms (i.e., ways of providing for student responses). Unlike TECEP it was developed in both manual and computerized forms.

The four functional elements of TDDA are: task description; training prescription; training hierarchy and sequence; and training cost. Tasks are described using specific action verbs and the piece of equipment acted on. Training is prescribed as to: learning algorithms; stimulus media; response acceptance mechanisms; method of instruction; and learning setting. Training hierarchy is the result of assigning tasks to resident training, on-the-job-training, or no training, while sequence is the specification of the order in which tasks are to be trained. Relative costs of feasible training alternatives are established through a cost-rating technique. Figure III-10 is a representation of TDDA.

The tryout of the task description element indicated that the use of Soldier's Manuals may not result in adequate task lists and that the action verb list may not be generalizable to all MOSs. The user of TDDA examines the MOS documentation to identify the actions performed by an operator and searches

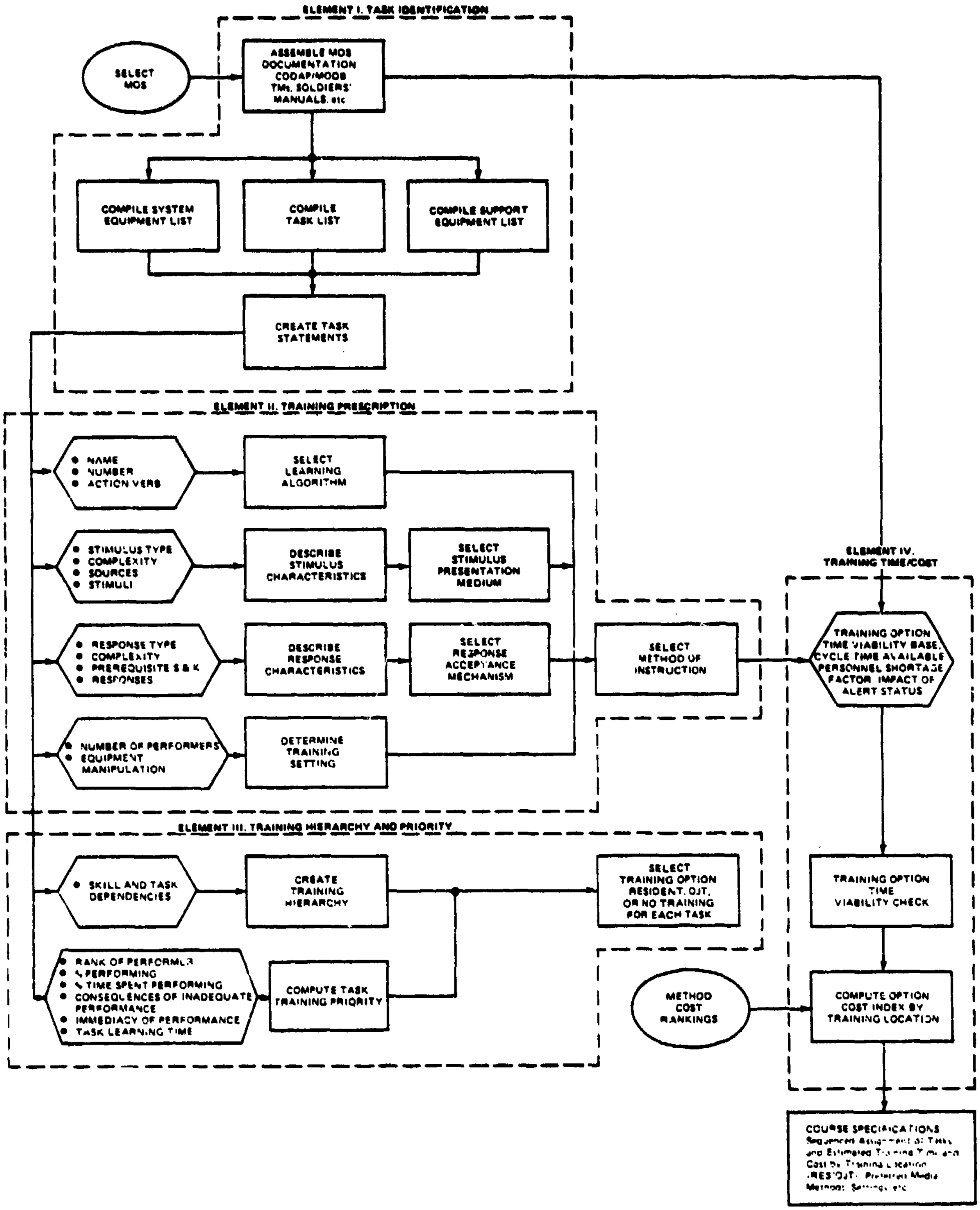

Figure III-10. The Training Developer's Decision Aid

the action verb list, a part of which is reproduced below, to find a verb that accurately describes the action performed. The user may find it difficult to decide which of several nearly synonymous verbs should be selected. The item of equipment acted on is added to the task description.

Training prescriptions use the task action verb to select one of twelve algorithms, which are models of instruction adapted from TAEG Report #16 (Braby et al., 1975) and TAEG #23 (Aagard and Braby, 1976). They are nearly identical to those in TRADOC Pamphlet 350-30, Interservice Procedures for Instruction Systems Development. Appendix A in Pieper et al., 1979, lists action verbs with the associated algorithms.

Having selected a learning algorithm, the user then selects the stimulus medium by identifying the general class of stimuli in the job environment and then further characterizes the stimuli by answering certain questions. The general classes of stimuli are verbal, audio, audio-visual, visual, and tactile. Several of the questions answered to further characterize the stimuli are:

- o Are the stimuli in color?
- o Are the stimuli equipment indicators?
- o Are the audio stimuli voice only?
- o Are the stimuli visually distinct (not obscured or overshadowed by peripheral stimuli)?

Answers to these questions lead to the selection of one or more of the following media types: audio tape, books with questions, microfiche film, mockup, movie, printed text, programmed text, real equipment, silent film strip, silent slides, simulator, sound film strip, sound slide, or television.

The TDDA requires the specification of the response acceptance mechanism. The general class of the response is first determined, and then the class is further characterized through a list of questions. The classes of responses are equipment manipulation, voice, written, and body movement.

Questions asked to characterize the responses include:

- o Is the task a maintenance task (one that requires access to the interior of the system)?
- o Are the manipulations discrete (as opposed to continuous as in tracking)?
- o Are the control displays of the equipment nonlinear?

The available response acceptance mechanisms follow. These are what the student acts on in training as he learns a task: audio tape recorder, books with questions, group instructor, mockup, question set, real equipment, simulator, teaching machine, tutor, and video recorder.

The stimulus medium and the response acceptance mechanism become the basis for the selection of the method of instruction. A set of methods compatible with both the stimulus medium and response acceptance mechanism is identified, and an optimal method (or methods) is selected by the number of matches between methods and several additional characterizations applied to both the stimulus medium and the response acceptance mechanism. The additional characterizations applied to the stimulus medium are as follows:

- o Pacing controller - what controls the speed of application for the presentation medium (program, student, or both)?
- o Stimulus content (visual, verbal, or audio)?
- o Next learning activity - what controls the presentations sequence of items (program, instructor, student)?

The additional characterizations applied to the response acceptance mechanisms are:

- o Pacing controller (student, instructor, program).
- o Next learning activity (program, instruction, student).
- o Type of evaluation (individual vs. group; selected vs. constructed).
- o Feedback (immediacy - immediate vs. delayed; source - intrinsic vs. extrinsic).

The method is selected from the following list: case study, computer-aided instruction, demonstration, games, group interview, guided discussion, in-baseket exercise, peer tutor, programmed instruction, programmed practical exercise, role playing, study assignment book, traditional classroom, traditional practical exercise, and tutoring.

If, for example, the pacing controller of the stimulus medium is the student, then computer-aided instruction, programmed practical exercise, and study assignment book are possible methods because all are compatible with this characteristic of the stimulus medium. The method most compatible with the characteristics of the stimulus medium and the response acceptance mechanism is selected.

On the basis of three criteria one of five learning settings is chosen. The three criteria are:

- o The number of students involved (a small number vs. 5 or more).
- o The nature of student interactions (individual vs. team).
- o Whether or not equipment manipulations are required.

Learning settings currently employed in TDDA are small group site, large group site, individual carrel, small group carrel, and traditional classroom.

Determination of the training hierarchy and sequence produces decisions about whether a task is to be taught in resident training, in OJT, or not at all. The decisions about the order in which tasks are to be taught are also made within this element.

The task training matrix, which contains all relevant task data (system equipment, support equipment, rank of task performer, task dependencies, etc.), is used to make these decisions. All tasks within a particular cell of the matrix are ordered hierarchically according to their interrelationships or dependencies. Decisions about whether a task is to be taught in resident training, in OJT, or not at all are made on the basis of six additional characteristics. These are:

- Percent members performing - the relative numbers of persons in the MOS who perform the task.
- Percent time performing - the relative amount of time each job performer spends performing the task.
- System readiness impact - the effect of task performance on the system's ability to perform its mission.
- Time to application - the period of time after arrival on the job before the task must be performed the first time.
- Task learning time - the number of hours required to learn the task on the job with the supervisor acting as tutor.
- Rank of task performer - the rank of the soldier who will perform the task.

TDDA training cost estimation is relative only, but detailed cost information may be developed after the selection of the most cost-effective option or options. A relative cost indicator is computed for each of the two training categories (resident training and OJT). Values for the two categories are then summed to yield a training option cost indicator. This indicator is to form a ratio that reveals the relative costs of the training options.

The training option cost indicator (TOCI) was developed by classifying all training methods and all direct and indirect training costs to derive a mean rating of each method. Each of the training methods was assigned to a cost class as follows:

Method Cost Class	Training Methods
1	Conventional Demonstration Case study Guided discussion
2	Peer tutor
3	Tutor
4	Programmed instruction
5	Traditional practical exercise
6	Programmed practical exercise
7	Computer-assisted instruction

All direct and indirect training cost variables were assigned to one of the following classes: square footage (i.e., space required), instructor-to-student ratio, system equipment, furnishings, expendable supplies, training aid development, and training materials development.

The various classes were combined in the cost rating matrix illustrated in Figure III-11. This matrix shows how costs vary as a function of training method and provides both a mean rating of each method and a cost multiplier. Hours spent in training in any method are multiplied by the cost multiplier to give the cost of training in that method. The sum of the method cost indicators summarizes costs for resident training and for OJT.

COST VARIABLE CLASS

METHOD COST CLASS	SQ FT	INST/ STU	SYS EQ	FURN	EXPEN SUPP	TNG AID DEV	TNG MAT DEV	MEAN RATING	COST MULTI-PLIER
1.	1	3	1.5	3	3.5	2	3	2.4	1.23
2.	3.5	4.5	3.5	3	3.5	2	1.5	3.1	1.35
3.	3.5	7	3.5	3	3.5	2	1.5	3.4	1.40
4.	3.5	1.5	1.5	5	3.5	5.5	5	3.6	1.43
5.	6.5	6	5.5	1	3.5	4	3.5	4.3	1.55
6.	6.5	4.5	5.5	6	3.5	5.5	6	5.4	1.73
7.	3.5	1.5	7	7	7	7	7	5.7	1.78

Figure III-11. Representative TDDA Cost-Rating Matrix

9. B-1 SAT (Sugarman et al., B-1 Systems Approach to Training, Final Report, Vol. I, July 1975)

The B-1 systems approach to training (SAT) developed a training program for the air-crew of the B-1 strategic bomber. It applied the techniques of systems analysis to instructional system development to assure that the entire training system would be considered within an orderly and complete process. ISD application is rarely as rigorous as in the B-1 SAT study.

SAT begins with analysis of missions into the successively more detailed levels of mission segment, function, task, and task element. The description of the task element includes the actual behavioral initiation cue, action verb, control, and completion cue. All task elements are then examined for commonalities, and a behavioral objective is developed to encompass each set of common task elements (Figure III-12). Behavioral objectives include a set of common task elements and information about the behaviors as initial conditions, concurrent behaviors, performance criteria, enabling objectives, crewmen responsible for the behavior and interactions among crewmen. Figure III-13 represents a task element while Figure III-14 represents a behavioral objective that encompasses that task element. The task analysis is supported by a computer program, called the sorting program, which includes a controls and displays catalog and an action verb thesaurus.

The controls and displays catalog contains such descriptive information as the names (and synonyms), locations, types, and subsystems of controls and displays, while the action verb thesaurus contains synonyms for action verbs used to describe behaviors. The task analyst uses the sorting program to store task information and to retrieve necessary equipment-related information. The use of the term "altimeter" or "rate of climb indicator" locates the information about the display called altimeter/vertical velocity indicator and records the correct term; the use of the action verb "respond" causes the more precise verb "reply" to be retrieved or stored.

All behavioral objectives, including enabling objectives, are arranged hierarchically and examined in light of the qualifications of a probable entering student. The tool supporting this determination was the personnel qualifications catalog, an example of which is presented in Figure III-15. The figure shows, for example, that an FB-111 pilot coming into the B-1 training program as a pilot would have been using a pitch and roll trim control identical to that of the B-1. The pilot with such a background is not given training on that control.

B-1 SAT identified training device requirements including method and media selection. Guidance for the identification of training device requirements was taken from the Navy's Training Effectiveness, Cost Effectiveness Prediction Technique (TECEP) (Braby, Henry, and Morris, 1974), modified to reflect the special requirements of the B-1 SAT.

Media/method selection is an aspect of the structuring and scheduling of courses, tracks, and instructional blocks. The tool employed to this end is the Training Resources Analytic Model (TRAM), a set of computer programs that examine proposed training system of resources, schedules, and costs. TRAM is similar to MODIA (Carpenter-Huffman, 1977), though it may not be as usable as MODIA, at least from the CTEA analyst's point of view.

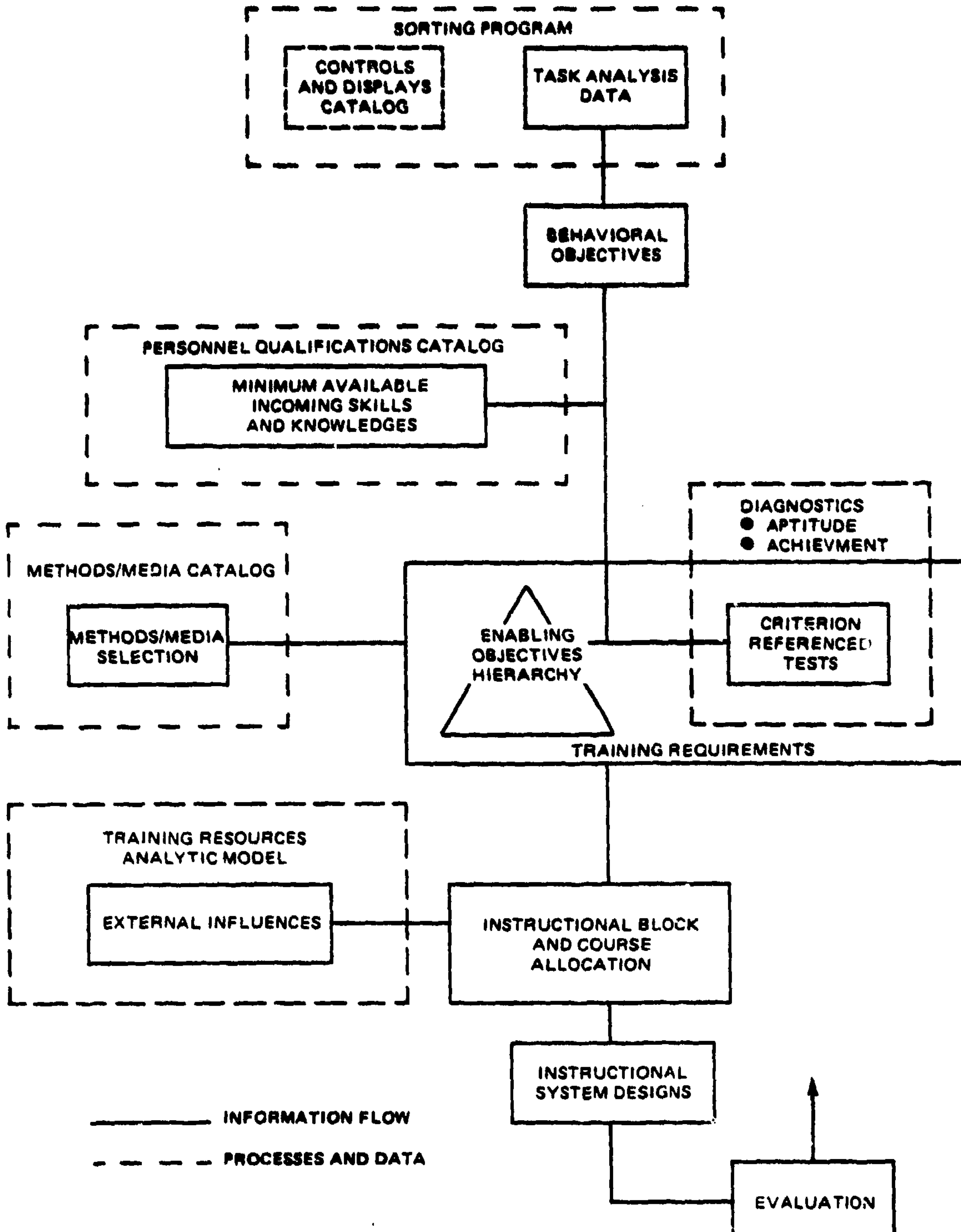

Figure III-12. Systems Approach to Training
(from Sugarman *et al.*, 1975)

BEHAVIOR
OF SETTING WING SWEEP ANGLE FOR CRUISE CONFIGURATION

		INITIATION CUE					COMPLETION CUE		
		CONTROL/ DISPLAY	RELATION	STATE	ACTION VERB	CONTROL OR DISPLAY	CONTROL/ DISPLAY	RELATION	STATE
		ALTIMETER	=	30000	ADJUST	WING SWEEP CONTROL	WING SWEEP INDICATOR	=	45
CONSTRUCTION	AND	POWER LEVEL INDICATOR	=	90					

Figure III-13. Example of Task Element Behavior (from Sugarman et al., 1975)

OBJECTIVE: Make a coordinated transition from climbing to cruise configuration.

INITIAL CONDITIONS:

VERTICAL VELOCITY: 2000	TEMP. AT DESIRED ALTITUDE: -55
POWER LEVEL: 100	DESIRED POWER LEVEL: 90
AIR SPEED: .5	DESIRED AIR SPEED: .8
ALTITUDE: 26000	DESIRED ALTITUDE: 30000
WING SWEEP: 13	DESIRED WING SWEEP: 45
A-V TRIMMED FOR CLIMB	

CONCURRENT BEHAVIOR: Heading remains constant

BEHAVIOR:

INITIATION CUE	ACTION	CONTROL OR DISPLAY	COMPLETION CUE
ALTIMETER = 29600	ADJUST	THROTTLES	POWER LEVEL IND. = 90
ALTIMETER = 29800	TRACK	PITCH IND. CONTROL STICK	PITCH IND. = 0 ALTIMETER = 30000
ALTIMETER = 30000 POWER LEVEL IND. = 90	ADJUST	WING SWEEP CONTROL	WING SWEEP IND. = 45
ALTIMETER = 30000 AIR SPEED = .8 WING SWEEP IND. = 45	ADJUST	TRIM	PROPRIOCEPTION = NEUTRAL PRESSURE

PERFORMANCE:
AIR SPEED = .8 (±kts) at cruise altitude.
ALTITUDE = 30000 (±ft) from desired altitude at cruise (TIME < sec).
SUBJECTIVELY SMOOTH VERTICAL FLIGHT PATH (e.g. REASONABLE g FORCES).
WING SWEEP = 45 (±deg.) after adjustment (TIME < sec).
HEADING ERROR = 0 degrees FROM DESIRED HEADING (±deg).

ENABLING OBJECTIVES:

CALCULATE	Necessary power level for cruise air speed. : altitude, temperature, desired true air speed.
CALCULATE	Necessary altitude to initiate power level change. : initial vert. velocity, desired altitude, air-speed, desired airspeed, A-V characteristics.
CALCULATE	Necessary altitude to initiate pitch change. : vert. velocity desired altitude, airspeed, A-V characteristics.
COORDINATE	Throttles and control stick to achieve a rapid transition having the g forces within a criterion without undershoot or overshoot.
PREDICT	Necessary pitch changes for level-off at desired altitude from the vertical acceleration and the rate of change in pitch.
TRACK	Pitch indication with control stick to remain at zero pitch at level-off.
TRACK	Heading indication with rudders and control stick to remain at desired heading throughout maneuver.

TASK ELEMENTS:

6.1.1.1	OPERATORS:	Pilot (and Copilot)
6.1.1.2	INTERACTIONS:	DSO provides heading data
6.1.1.3	TIME:	Indefinite, depending upon conditions
6.1.1.4	CRITICALITY:	2
	DIFFICULTY:	2

Figure III-14. Behavioral Objective Illustrating a Maneuver (from Sugarman *et al.*, 1975)

ITEM	CONTROL DISPLAY CODE	USING CREW MEMBER	FB-111	
			P	N
FLIGHT CONTROL STICK	S1-1	P-CP	A	
SCAS PITCH SWITCH FLIGHT TEST ONLY	S1-2.1	(P)-CP	C	
SCAS ROLL SWITCH FLIGHT TEST ONLY	S1-2.2	(P)-CP	C	
SCAS YAW SWITCH FLIGHT TEST ONLY	S1-2.3	(P)-CP	C	
STICK SHAKER SWITCH	S1-2.4	(P)-CP	B	
STANDBY PITCH TRIM CONTROL	S1-3.1.1	P	C	
YAW TRIM CONTROL	S1-3.1.2	P	C	
STANDBY PITCH TRIM CONTROL	S1-3.2.1	CP	C	
YAW TRIM CONTROL	S1-3.2.2	CP	C	
TRIM FOR TAKEOFF SWITCH	S1-3.2.3.1	(P)-CP	C	
TRIM FOR TAKEOFF LIGHT	S1-3.2.3.2	P-VP	C	
PITCH & ROLL TRIM CONTROL	S1-3.3	P	A	
PITCH & ROLL TRIM CONTROL	S1-3.4	CP	A	
PITCH TRIM SWITCH	S1-4.1	P-CP	C	
ROLL TRIM SWITCH	S1-4.2	P-CP	C	
YAW TRIM SWITCH	S1-4.3	P-CP	C	
PITCH AUGMENTATION SWITCH	S1-4.4	P-CP	C	
ROLL AUGMENTATION SWITCH	S1-4.5	P-CP	C	
YAW AUGMENTATION SWITCH	S1-4.6	P-CP	C	
FLIGHT CONTROL STICK DISCONNECT	S1-5	P-CP	D	

CLASSIFICATION OF INCOMING ABILITIES

- A – PRESENTLY USING IDENTICAL EQUIPMENT
- B – PRESENTLY USING EQUIPMENT WITH IDENTICAL FUNCTION BUT DIFFERENT OPERATION
- C – PRESENTLY USING EQUIPMENT FOR SAME PURPOSE BUT FUNCTIONALLY DIFFERENT
- D – NEVER USED COMPARABLE EQUIPMENT

Figure III-15. Example of Personnel Qualification Matrix (adapted from Sugarman *et al.*, 1975)

B-1 SAT has three determinants for the scheduling of instruction: the hierarchy of objectives, the instructional context, and resource management. The hierarchy identifies dependencies within the content structure; that is, what must be learned so that the next skill or knowledge may be acquired. The instructional context refers to the system or the phase of flight with which learning is concerned. The sorting program allows the analysts to search the data base to determine all objectives associated with a particular system or phase of flight and then to group or not group the objectives on such a basis depending on the outcome of tradeoff analyses. TRAM is the means of conducting the tradeoff analyses between resources and contexts. Grouping objectives within a certain instructional context may be indicated by the commonalities among objectives but contradicted by the cost of using training devices and facilities in such a way.

Because students of B-1 training programs were to come from different sources, and would thus have different entering skills and knowledge, different tracks were developed for each distinct source of students, and were examined by TRAM for total cost-effectiveness.

10. Army CTEA Methods in Current Use

Army analysts, such as those in the TRADOC schools having proponency for the developing weapon systems, perform CTEA using a number of techniques. These techniques were developed in response to severe constraints on input data. They represent what is feasible for the analysts at present and what the present research aims to build upon and improve. Many of their methods and processes are pertinent to a general model for CTEA in the LCSMM and are reviewed here to identify and describe those processes.

Some of the current CTEA methods are applied to implemented systems rather than systems still in the acquisition process, but their methods and processes are relevant to CTEA conducted after DT/OT results are available. Other of the CTEA apply to early stages in the acquisition process. The studies reviewed were:

- DIVAD Gun CTEA
- Improved Hawk (Hawk PIP) Training Development
- Roland Training Development
- Improved TOW Vehicle (ITV) CTEA
- Diagnostic Rifle Marksmanship Simulators (DRIMS) CTEA
- Bridge '85 CTEA
- XM1 Tank Training Devices CTEA
- LAW WSTEA
- M16 Rifle WSTEA

Procedures in the DIVAD Gun CTEA are applicable as early in the LCSMM as the conceptual phase, where they are used to generate task lists, and later through all stages until the comparison of training program alternatives. The other CTEA applicable for generation of task lists are the Improved Hawk CTEA and Roland Training Development method. The DRIMS CTEA contributed procedures for comparison of training program alternatives. Both DRIMS and the ITV CTEA contain methods for the resolution of CTEA issues in the LCSMM.

A. The DIVAD Gun CTEA. When the DIVAD gun system was nearing DT/OT II the data available for CTEA corresponded to the conceptual phase. There were no task data and few other forms of data. The CTEA was conducted on the basis of knowledge about the class of weapon systems to which the DIVAD gun belongs. There are certain tasks or types of tasks that are common to weapons of this class, and there is a great deal of information about the training of these tasks from prior research. On the basis of this general information, and without task information, the CTEA analyst drew upon prior documentation and subject matter experts to formulate three training program alternatives and to estimate the effectiveness and costs of the alternatives. One of the alternatives had the highest effectiveness estimate at lower cost and was therefore selected.

The procedures used in this CTEA represent a "generic" type based on prior research, prior or existing weapons similar to the developing system, and subject matter expertise.

B. Improved Hawk (Hawk PIP) Training Development

One of the processes of the Improved Hawk training development effort corresponds to a potential CTEA process, the generation of a task list. Improved Hawk is a modification of the Hawk design rather than a redesign, so many of the tasks of the former are identical to those of the latter, and the training, training requirements, and training implications are also identical. Where tasks have been added or changed new tasks were defined by inferring tasks from the manufacturer's draft technical manual (TM). Figure III-16 is a reproduction of a task analysis sheet prepared by the training developers; the inferred tasks are listed at the left, and task analysis data (MOS to be trained and locations of training) are at the right. A source of this information is the page of the manufacturer's draft TM. Documenting information was not always adequate so the training developers worked through them on actual equipment.

Once the new tasks were defined they were used to develop new training. To the extent that similar tasks were known to exist in other systems, the training of these similar tasks guided the development of training for the new tasks. For other tasks they developed training through standard ISD procedures.

C. Roland Training Development

The Roland task analysis procedure represents what a CTEA analyst might do given adequate data. Closely following standard ISD procedures and using the manufacturer's Logistic Support Analysis Record (LSAR, D Sheets) and draft TM, the task analyst developed a task list. Employing expert judgment developed through the manufacturer's training course as well as broad experience in Air Defense, he/she made certain revisions in the task descriptions provided by the manufacturer. He/she then analyzed the task list to identify critical tasks and to determine training locations of tasks.

MATRIX TASK INVENTORY												
TAS CRITICAL TASK LIST / TASK/CATEGORY	MOS					TRAINING LOCATION						
						OJT	RESIDENCE	EXTENSION		JOB AID		
DUTY: PERFORM CHECKS AND ADJUSTMENTS												
TASKS:												
1. Check TAS operations	16 E	24 E	24 G			X		X		X		
2. Set up TAS local control unit	16 E	24 E	24 G			X		X		X		
3. Check TAS interface electronics BITE	16 E	24 E				X		X		X		
4. Check and adjust TAS video conditions	16 E	24 E	24 G			X		X		X		
SUBTASKS:												
4a. Check/adjust vertical roll	16 E	24 E	24 G									
4b. Check/adjust horizontal roll	16 E	24 E	24 G									
4c. Check/adjust humbars	16 E	24 E	24 G									
4d. Check/adjust image focus	16 E	24 E	24 G									
4e. Check/adjust mirror resolution	16 E	24 E	24 G									

Figure III-16. Reproduction of Part of Matrix Task Inventory Sheet

D. ITV CTEA (TRADOC, Cost and Operational Effectiveness Analysis for the Improved TOW Vehicle (ITV), Part IV, Cost and Training Effectiveness Analysis, June 1978)

This CTEA was originally conducted as a part of the COEA done, presumably during Phase III, Full-Scale Development, but was subsequently updated to provide for training development needs. It is of interest methodologically because it presents an examination of costs as a function of training location (i.e., different Army training centers) rather than as a function of different media-method combinations. It assumes that the training alternatives are equal in effectiveness.

E. DRIMS CTEA (USAIS, Diagnostic Rifle Marksmanship Simulators Cost and Training Effectiveness Analysis, August 1978)

This CTEA compared the costs and effectiveness of four approaches to remedial rifle marksmanship training. Because of the high rate of failure in rifle marksmanship courses, remediation is expensive and, conducted with the M16 rifle and ball ammunition, possibly limited in effectiveness. Three rifle marksmanship simulators were considered as alternative approaches to remedial training. These were the Weaponeer, the Lasertrain, and the Caliber .22 Rimfire Adapter (RFA).

This study is of value to the development of general CTEA methods primarily because of the procedure followed to rank the alternatives: the rankings of the alternatives on four separate factors were combined to give an overall, or final, ranking.

This procedure is illustrated in Table III-3. The four ranking factors are relative training effectiveness, relative cost, relative capability, and relative user acceptance. Rankings on each factor were derived as follows:

o Relative training effectiveness was given in terms of the probability of a hit during record fire for soldiers given remedial training with different alternatives. These data were obtained from previously conducted studies. Relative training effectiveness (RTE) is defined as the overall probability of hit (P_H) associated with an alternative divided by the probability of hit associated with the baseline case, which was the M16 rifle firing ball ammunition. Thus, the RTE of the M16 rifle firing ball ammunition was 1.0, while the RTE of the Weaponeer, for example, was 1.01 because the P_H associated with it was slightly higher than the P_H associated with the M16 firing ball ammunition.

o Relative costs are defined as the life-cycle costs of the alternative over the life-cycle costs of the base case, which is the M16 rifle firing ball ammunition. Because the RFA can simulate 25-meter fire but not record fire, its life-cycle costs were compared only with the 25-meter component of M16-ball ammunition life-cycle costs.

o Relative capability is defined, simply, as the number of critical skills taught by an alternative over the total number of critical skills of the M16-ball ammunition base case. The relative capability of the M16-ball ammunition base case is 1.0, of course, while the three simulators have a somewhat lesser capability for teaching critical skills.

Table III-3. Ranking Factors and Ranking of Training Alternatives (from DRIMS CTEA, 1978)

RANKING FACTORS	M16	WPNEER	LTRN	RFA
	BASELINE ALTERNATIVES			
RELATIVE TRAINING EFFECTIVENESS (RTE)				
Record Fire P_H	1.0	1.01	0.99	1.00
Relative Training Effectiveness Rank	(1)	(1)	(1)	(1)
RELATIVE COST (RC)				
a. Table 4, Section V	1.0	0.08	0.05	0.10
b. Relative Cost Rank	(4)	(2)	(1)	(3)
RELATIVE CAPABILITY (RCP)				
a. Table IV-I	1.0	0.86	0.50	0.64
b. Relative Capability Rank	(1)	(2)	(4)	(3)
RELATIVE USER ACCEPTANCE (RUA)				
a. CET of Weaponeer & Lasertrain dated Oct 77	1.0	4.33	1.0	0.33
b. Relative User Acceptance Rank	(2)	(1)	(2)	(3)
TOTAL OF RANKINGS (LOWEST SCORE MOST COST AND TRAINING EFFECTIVE)	(8)	(6)	(8)	(10)
FINAL ALTERNATIVE RANKINGS	(2)	(1)	(1 (2)	(3)

o Relative user acceptance is defined as the number of trainers who preferred an alternative training device divided by the number who preferred the M16 rifle-ball ammunition base case.

The rankings of the four alternatives of each of the four factors were summed to yield overall ranking scores such that the lower the score the higher the overall ranking.

F. Other Current CTEA Methods

The remaining CTEA methods reviewed (Bridge '85, XM1 Tank, LAW, and M16 Rifle) were of general interest for their processes, but did not contribute methods other than those already described. The LAW and M16 Rifle weapon system training effectiveness studies represent methods applicable to fielded systems which are secondary to the present research.

11. Methods for the Analysis of Training Devices/Simulators

The process through which training devices/simulators are selected and developed for evolving materiel systems is complex and detailed. The entire process does not fit within the limited scope of CTEA. However, CTEA may impact on it at several points: first, to identify the need for a training device; later to estimate the costs and effectiveness of proposed training devices alternatives; and compare alternatives with and without training devices with various combinations of training devices. No special CTEA is necessary for the identification of the need for a training device/simulator, nor for the comparison of training program alternatives with varying levels of training device use. The estimation of the effectiveness of proposed training devices and simulators does require a special method. The prescription or development of training device and simulator characteristics is clearly beyond the scope of CTEA properly conceived.

Wheaton et al. (1976) reviewed a number of methods for estimating the effectiveness of proposed training devices and simulators and have found them to be generally inadequate. They proposed a new method based on the assessment of training variables (tasks, behaviors) and device variables (appropriateness, efficiency, effectiveness). It has apparently been useful for estimating the effectiveness of proposed devices, but its validity remains to be tested.

The method developed by Wheaton et al. (1976) considers training device effectiveness as "a function of the transfer potential of the device, the learning deficit of the trainees, and the extent to which appropriate training techniques are utilized in the device (p. 7)." Transfer potential is given first as a function of the commonality of tasks in the training situation and the operational setting, and second as a function of the similarity of the training device and the operational equipment. The learning deficit is the difference between entering proficiency and the proficiency required by the operational task. The extent to which a device employs appropriate training techniques is determined by an evaluation of each subtask trained by a device in terms of about one hundred principles and techniques; each subtask thus results in a rating of the device as a potential means for overcoming the learning deficit represented by the task. The transfer potential, learning deficit, and training techniques analyses are combined to produce a device effectiveness rating for each subtask, and these separate ratings are then combined to yield an overall effectiveness rating for the device.

TRAINVICE has been proceduralized for use by Army personnel with experience in task analysis and the development of training objectives. Five analyses are necessary to apply the method:

- o Task commonality analysis
- o Physical similarity analysis
- o Functional similarity analysis
- o Learning deficit analysis
- o Training technique assessment

The procedures for each of these analyses are given in the manual. According to the authors of the method, these procedures represent an intermediate rather than an exhaustive level of detail and thus yield an acceptable degree of precision while avoiding the extensive efforts required by other methods for estimating the effectiveness of training devices.

Training Device Requirements Document Guide: A Procedures Handbook for Directorate of Training Development Project Offices for Devices (PM TRADE, 1979) includes the TRAINVICE procedures for estimating the effectiveness of devices as an aspect of developing training device requirements. It also includes procedures for media analyses to be employed within the process through which an expressed training device need is analyzed to determine whether a training device requirement should be developed or the need should be met by alternative media. If an expressed training device need is justified, other procedures are undertaken to produce a training device requirement; these include the TRAINVICE procedures. Other procedures of the training device requirement development process are concerned with the formulation of training device concepts, cost analysis of alternative training concepts, and validation of training device concepts. In general, although in less complex form, the procedures specify a LCSMM approach to the development of a training device and thus include as an aspect of analysis separate CTEA.

SECTION IV

CTEA METHODS DEVISED BY LITTON

To meet recognized CTEA methodological needs, Litton has revised or developed three methods: an empirical method for the prediction of training programs and the estimation of their effectiveness; an interim method for dealing with the issue of trainability while more refined methods are under development; and a cost model.

A. The Analogous Task Method (ATM)

ATM takes advantage of information obtained in the process of training soldiers for fielded weapons systems. This information is brought to bear on training estimation and assessment questions early in the acquisition process of a developing weapons system. The fundamental link is the identification of a task or tasks on fielded weapons systems whose characteristics are comparable or analogous to a task on the developing system. Having established the link, the details of training for the analogous task (fielded system) can be used to estimate the requirements for the target task (developing system). Furthermore, the performance of soldiers on the analogous task and the cost of training to proficiency can be used as estimates of corresponding quantities for the target task.

The method is applied on a task by task basis with an overall estimate of training effectiveness calculated from the task estimates. When discrepancies are found between proposed training plans and training for the analogous task, the training plans are marked for further investigation. Likewise when the assumed effectiveness of training or its cost differ markedly from measures of analogous task training, training for those tasks is also marked for study.

ATM method has six steps: (1) definition of the critical tasks to be performed on the developing system (the target tasks); (2) classification of the target tasks to provide a basis for finding the analogous tasks; (3) analogous task identification and selection; (4) assessment of training for the analogous tasks; (5) generation of estimates of training for the target tasks; and (6) aggregation of the effectiveness and cost measures across all tasks to obtain a picture of training for the developing system as a whole.

1. Step 1: Task Definition

The basic data of the empirical method are the description of those operator and maintenance tasks essential to weapons system operation and mission accomplishment. This list is compiled initially either by the manufacturer or proponent school early in the conceptual phase of the LCSMM. Without the list of tasks, the analysis cannot proceed. The analyst must either wait for the task list to be produced or attempt to compile one. A critical task list may be assembled by the analyst from a step by step description of system operation obtained from the manufacturer's technical personnel. Where the concept is sufficiently advanced, construction of a mock-up aids the exact description of the tasks. When the Logistical Support Analysis Record (LSAR) is available, the task descriptions on Sheet D (Figure IV-1) and the Failure Analysis on Sheet B (Figure IV-2) can be used to verify critical tasks.

DATA SHEET D: MAINTENANCE AND OPERATOR TASK ANALYSIS

TASK NO.	SEQUENTIAL TASK DESCRIPTION
	NOTE: POWER PACK MUST BE REMOVED TO REPLACE ENGINE
01	REMOVE SEAT BY REMOVING SEAT RETAINING PINS.
02	REMOVE BATTERY COVER, DISCONNECT GROUND CABLE (3/4 IN WRENCH).
03	REMOVE GEAR SHIFT KNOBS, SHIFT LEVER BOOTS AND TRANSMISSION PLATE (FLAT-TIP SCREWDRIVER)
04	DISCONNECT SPEEDOMETER CABLE AND ELECTRICAL CABLES (½ IN WRENCH)
05	REMOVE SHIFT AND PARKING BRAKE LEVERS (3/4 IN WRENCH AND SCREWDRIVER).
06	REMOVE BOLTS SECURING FRONT AND REAR PROPELLER SHAFTS (7/8 IN WRENCH)
07	REMOVE REAR SUPPORT MOUNTING BOLTS (7/8 IN WRENCH).
08	REMOVE CLAMP SECURING MUFFLER INLET PIPE AND EXHAUST PIPE. REMOVE MUFFLER INLET PIPE FROM MANIFOLD (FLAT-TIP SCREWDRIVER AND 9/16 IN WRENCH)
09	REMOVE BRUSH GUARD ASSEMBLY (9/16 IN WRENCH)
10	ATTACH ENGINE HOIST (REF. TM XX-XXXX-XXX-23 FOR PROPER HOOK-UP AND USE OF HOIST).
11	WARNING: PLACE CONTAINER UNDER FUEL LINE BEFORE DISCONNECTING LINE (3/4 IN WRENCH)
12	DISCONNECT ELECTRICAL WIRING HARNESS.
13	REMOVE LEFT AND RIGHT FRONT ENGINE MOUNTING BOLTS (3/4 IN WRENCH)

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Figure IV-1. Logistical Support Analysis Record Sheet D

DATA SHEET B: ITEM RELIABILITY (R) AND MAINTAINABILITY (M) CHARACTERISTICS

COVER MODULE HOLDER

FAILURE ANALYSIS

Failure Mode	Failure Symptoms	Failure Effect and Criticality
FASTENER DAMAGED	VISUAL INSP	NONE
COVER DAMAGED	VISUAL INSP	NONE

ITEM FUNCTION

COVER PROVIDES MEANS OF RETAINING MODULES AND DIRECTING AIR FLOW AROUND THEM.

QUALITATIVE MAINTAINABILITY REQUIREMENTS

FAULT DETECTION IS ACCOMPLISHED BY VISUAL INSPECTION DURING OFF-LINE CHECK OUT ROUTINES AND CORRECTIVE MAINTENANCE.

MAINTENANCE CONCEPT

OPERATOR/CREW INSPECTION

ORGANIZATIONAL MAINT: REMOVE/REPLACE COVER. REPAIR BY REPLACING FASTENERS.

REMARKS

REF. -B05: ITEM #21 & 22 - TPQA CONSIDERS SKILLS AND TRAINING PRESENTLY INADEQUATE

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Figure IV-2. Logistical Support Analysis Record Sheet B

The verbs that describe the actions performed by the soldiers must specify the nature of the action. These verbs will be used in the following step as a basis for classifying the task. Verbs like "perform", "accomplish", "continue", or "operate" are too general to allow proper classification. As a guide to the appropriate level of specificity, the analyst should compare the verbs in his list with those in the task verb list (acceptable) and the general verb list (not acceptable). Those description whose verbs are too general should be rewritten with more specific verbs. It is likely that, on rewriting, the "task" will prove to be a group of tasks, each of which should be considered individually. The task verb list is presented in the CTEA Performance Guide.

2. Step 2: Task Classification

The target task is classified by the action verb in the task description, the body of knowledge the soldier must understand as general background to task performance, the stimuli provided by the equipment to initiate the task, the response made to that stimulus, and the feedback provided by the system to indicate proper or improper performance of the task. The task type is determined by the action verb and the knowledge context for each task. The action verb is compared with those in the task verb list. The list gives the task type to which each verb meaning has been assigned. If the verb does not appear in the task verb list, then the verb should be compared with the descriptions and examples of each type which appear in the synonym list The verb may be an unlisted synonym for one of the verbs in the synonym list. If not, the analyst should assign the verb to that category which most closely describes it. The synonym list appears in Annex C, Appendix 2 of the CTEA Performance Guide.

The task categories, in some cases, include widely differing tasks which cannot be distinguised solely on the basis of the verb. One basis for distinguishing subcategories is the knowledge context of the task. For example, computer tasks can be distinguished from electronics tasks or mechanical tasks even though they all involve following procedures. (A list of knowledge contexts is given at the end of the synonym list.) If the appropriate context does not appear, the task type should be used without an associated context.

The determination of stimulus, response, and feedback types follows the classification of Jorgensen and Hoffer (1978). The analyst examines the task description and determines which stimulus, response, and feedback categories best fit the task. The stimuli are characterized as to modality (visual, auditory, tactile, etc.), nature over time (static or dynamic; frequency of change), number, and organization (formatted or not; simple or complex patterns). Responses are characterized by mode of implementation (verbal, written, manipulating, etc.), nature over time (static or dynamic; frequency of change), number, and organization. Feedback is characterized by modality (visual, aural, written, etc.), time relationship to the preceding response and the following stimulus, regularity, and frequency.

3. Step 3: Analogous Task Identification

As more CTEA are performed the resulting data may be stored in a central training data base to facilitate future identification of analogous tasks. In the short term, the analyst must identify the analogous task intuitively. The first place to look for an analogous task is the previous generation weapons systems being replaced. If the weapon system is composed of major

subsystems (e.g., radar tracking, missile launcher), then a comparable subsystem on another weapons system may provide the analogous tasks needed. If comparable subsystems cannot be found, the analyst must look for individual tasks.

To be an analogous task, the task on the fielded weapons system must be in the same task type, have the same knowledge context (if any), and have the same response type. In addition, the analogous task must have lesson plans or materials which describe the training for it in detail. If an analogous task cannot be found, then an analytical procedure (e.g., TEEM or TECEP) must be used to identify necessary training elements. The assessment measures obtained from these methods do not directly estimate or predict the performance of soldiers resulting from a training program.

If more than one potential analogous task is identified, the analyst should attempt to choose among them. The choice is determined by the remaining task information (i.e., other than the minimum criteria): the specific task verb, the specific response, the stimulus type, the necessary conditions. These criteria should be considered in the order given. Only tasks identical on a prior criterion should be evaluated on a later one.

4. Step 4: Training Assessment for the Analogous Task

For each analogous task identified, the analyst must obtain the details of training. These details will be contained in the training programs and materials and the specifications for training devices used in conjunction with training.

The analyst must also obtain performance information to be used as a measure of the effectiveness of training. The measure is defined as the proportion of soldiers achieving criterion performance on the task following training. If data from the hands-on portion of the Skill Qualification Test (SQT) are available for that task, then they should be used to calculate effectiveness. If not, the written portion should be used in their place. Where no SQT data are available, data from an end-of-course test should be used. In the absence of all formal assessment tests, the instructor should be asked to estimate the proportion of soliders who learn the task.

5. Step 5: Training Assessment for the Target Task

The training on the analogous task can be used as the training plan for the target task if no plan has been formulated. If there is a training plan, then differences between the training plan and analogous task training will indicate potential difficulties in training to be watched for in operational testing.

If the training for the target task is identical to that of the analogous task, the effectiveness measure for the analogous task becomes the estimate of effectiveness for target task.

If the training differs, the effectiveness in Step 4 becomes a criterion against which the proposed effectiveness is compared. Care must be taken that the criterion dimensions for the two are the same. If more than one analogous

task has been identified, the data can be combined in the following manner. If the training is roughly the same, the effectiveness measures should be averaged to obtain the estimate of effectiveness for the target task. If the training differs among the analogous tasks, that with the highest effectiveness measure should be chosen.

As data on training are obtained from OT I and OT II, the direct estimates for performance on the task should be substituted for the measures based on analogous tasks.

Since training for different tasks may develop at different rates or analogous tasks may be found for only some of the critical tasks, it is entirely possible that some of the tasks will have only analytical measures while others have performance measures. Therefore, combining measures into a single aggregate effectiveness measure will not be meaningful. Even if all measures are performance measures, a reasonable set of weights for combining the measures may be difficult to deduce. In both cases, a verbal rather than numerical overview of training is suggested.

The method is illustrated in Figure IV-3. Each rectangle represents a step of the process, while the processes indicated in the circles show the relationship of the process to other processes of a general CTEA model to be described in Section V (Figure V-1).

B. Trainability Analysis

Once tasks have been identified and alternative means of training those tasks have been predicted or developed, it is necessary to determine that, given the characteristics of the personnel who will man the system, the tasks can be trained to required levels of proficiency. The purpose of trainability analysis, thus, is to examine the interactions among tasks (especially standards), training program alternatives, and system personnel characteristics.

The review of the literature, however, has revealed no explicit method for trainability analysis. According to a TRADOC official (Telephone Interview, 26 June 1980), however, such methods are now under development and will probably be available at some time in the future. This official agreed that it would be reasonable to apply the following stopgap method in the interim.

The objective of this method is to identify tasks that are of great or moderate concern as regards the trainability issue. Once those tasks have been identified, certain trade-offs may be considered and recommended: the revision or reconsideration of certain training program alternatives; the alteration of system concepts or designs; and the revision or establishment of personnel selection criteria.

The risk that a task cannot be adequately trained given an existing or predicted training program and system personnel characteristics is judged to be high, moderate, or low. Each system task is thus evaluated against each training program alternative. The criticality of each task is also judged to be high, moderate, or low. These twin evaluations are then used to form a trainability analysis matrix for each task as trained by each training program alternative. The matrix is illustrated in Figure IV-4. The cells indicate the level of the

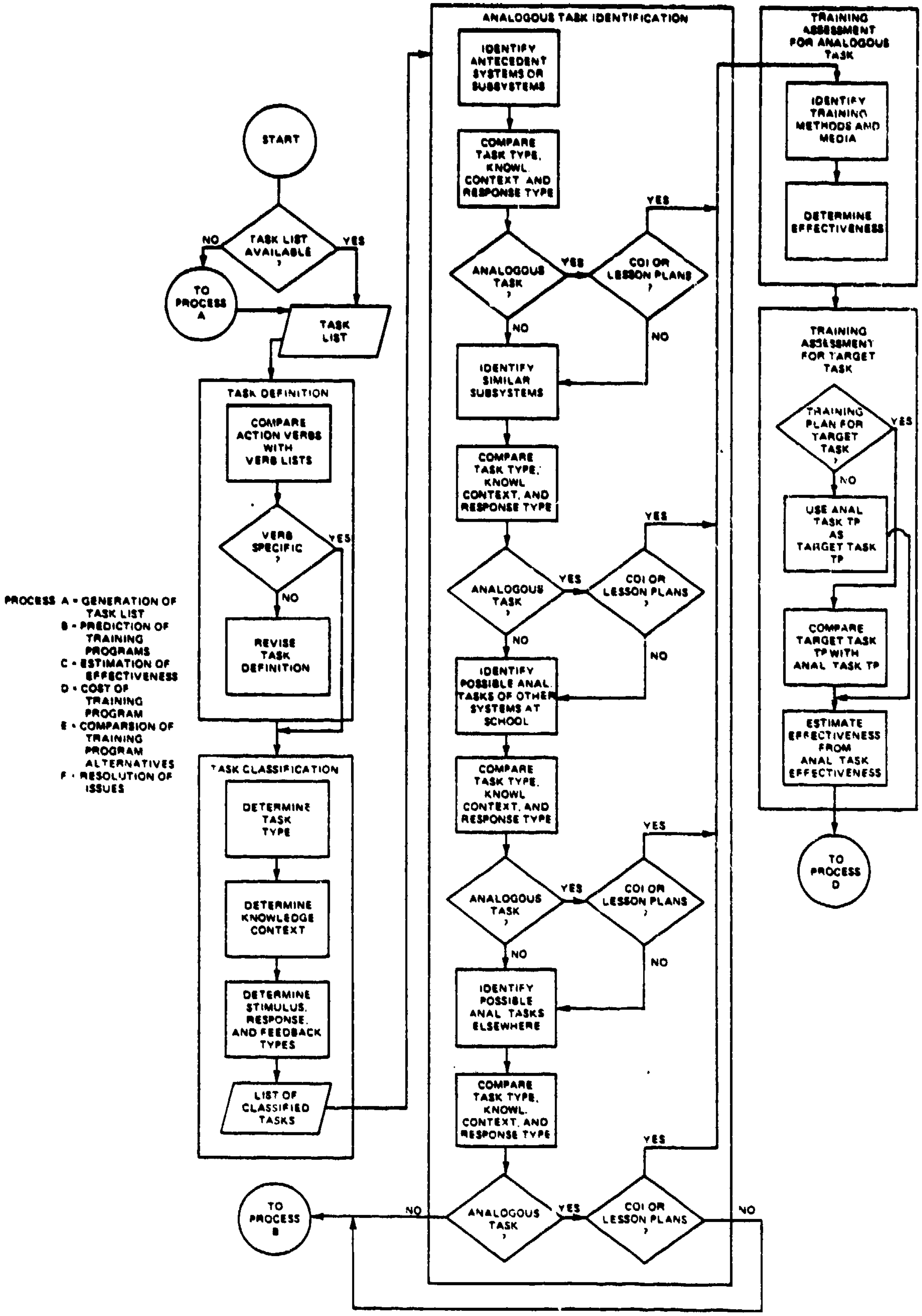


Figure IV-3. Analogous Task Method

analyst's concern. Where concern is great or moderate, the analyst must resolve it by conducting trade-off analyses (above) or by calling attention to the concern and recommending additional studies.

TRAINING RISK

TASK CRITICALITY	HIGH	MODERATE	LOW
HIGH	Great concern	Moderate concern	Little concern
MODERATE	Moderate concern	Moderate concern	Little concern
LOW	Little concern	Little concern	Little concern

Figure IV-4. TASK TRAINABILITY ANALYSIS MATRIX

C. The Cost Process Model

Because resources are limited and costly, choices among alternative systems or programs must be based on the allocation of these resources among competing demands. For example, if more than one alternative satisfies the mission-requirement (equal effectiveness), the least costly alternative is preferred. Obviously, the cost analyses, whether it be absolute or incremental, in a CTEA is essential.

A cost model orders and simulates the many actions involving the expenditures of resources (including time) for, in this case, Army training. The cost model allows the analyst to predict or recapture in a systematic manner those expenditures of resources that were or will be germane. The first requirement of a model is that it be relevant to the need, i.e., be able to predict or capture the costs of training Army tasks or systems. Army training takes place in the institution (schools) and in the units. Most of the institutions have base or classroom instruction and instruction in the field. Institutional base training can be self-paced or instructor oriented. There is individual training and collective training in the Army. An Army training cost model should be Army oriented and have the capability of estimating training costs that consider all pertinent variables.

During the literature review, Litton reviewed many cost models and approaches to costing of training, eleven of which have been abstracted and appear in Appendix C. Litton sought a model that would provide the capabilities required rather than to design a new one. None met all the requirements. For example, the Army Life Cycle Cost Matrix, although Army oriented, is better structured

for and focused on budgetary, finance, and accounting purposes rather than CTEA. The TECEP model is focused on institutional base training but could be modified to meet the other requirements. However, complete modification of the TECEP model results in the Litton proposed cost model.

The CTEA analyst must retain a high degree of flexibility in relating the form of the data available with the equations herein. For example, where the equations contain variables on a "per student" basis, these variables are usually then multiplied by the average number of students to obtain total costs. If, however, total cost data are already available, then these should be entered directly as the product of both of the variables.

The Litton cost model is designed to capture the significant costs of training a task or an entire program. If cost elements are available on a training program basis, then the model output will be the total cost estimate of the training program. More likely, the CTEA analyst will have to deal with analogous tasks and will have to iterate the model for each such task. The grand total of the costs of training all the tasks, of course, will give a cost estimate of the training program.

The Litton cost model is intended to aid the CTEA analyst to prepare recommendations to the decision maker regarding choices among alternatives. It is not intended for budgetary purposes. The Litton model, however, captures personnel and unit costs in order to convert training time and differences in grades of personnel involved into a measure compatible with the other factors in the decision process: dollars.

It is necessary for the CTEA analyst to have some understanding of the Five Year Defense Plan (FYDP) and its associated budget programs to assist in data collection. Figure IV-5 shows the ten Army programs currently in use.

Represented by the programs and subprograms are resources: people, money, materiel, and facilities. It would appear that all people, money, materiel, and facilities required for training would be provided under Program 8T, training. This, however, is not the case. Program 8T carries resources for almost all institutional training but training resources are found also in Programs 2, 3, 5, 6, 7M and 8M. Program 2, for example, carries training resources for the individual and the collective training of personnel in General Purpose Forces. On the other hand, such activities as training developments, combat developments and direct assistance to unit training by institutions are not technically institutional training but are accounted for in Program 8T. Institutional training of individual medical skills is accounted for in Program 8M.

The CTEA analyst must also understand where various levels and types of training are trained. Figure IV-6 is a matrix which shows this. (It should be noted that the term One Station Unit Training (OSUT) is not unit training but refers to the institutional training program that combines aspects of basic training (BT) and advanced individual training (AIT) while the trainee is assigned to one training unit.) The matrix portrays the usual situation. There are rare exceptions where, for a special system, some crews/teams will be given collective training in the institution.

Program 1	-	Strategic Forces
Program 2	-	General Purpose Forces
Program 3	-	Intelligence and Communications
3C	-	Communications
3I	-	Intelligence
3O	-	Other
Program 4	-	Airlift/Sealift
Program 5	-	Guard and Reserve Forces
Program 6	-	Research and Development
Program 7	-	Central Supply and Maintenance
7S	-	Supply
7M	-	Maintenance
Program 8	-	Training, Medical, and Other Personnel Activities
8T	-	Training
8M	-	Medical
8O	-	Other
Program 9	-	Administration and Associated Activities
Program 10	-	Support of Other Nations

Figure IV-5. Army FYDP Programs

	Institution		Unit
	Base	Field	G, L, M
Individual Training	OSUT or BT+AIT		Tasks not taught to proficiency at institution Refresher training
Collective Training			G, L, M Essentially all collective tasks

OSUT - One Station Unit Training

BT - Basic Training

AIT - Advanced Individual Training

G - Garrison

L - Local Training Area

M - Major Training Area

Figure IV-6. The Army Training System

The Litton cost model concentrates on the initial individual and collective training required to attain proficiency on the system and operational capability. Costs attributable to refresher training are omitted. Proficiency is assumed when the soldier successfully completes the appropriate SQT and the crew/team successfully completes the appropriate section of the Army Training and Evaluation Program (ARTEP).

The costs of training can be either direct or indirect. Direct costs associated with institutional training consist generally of the following:

1. Pay and allowances of instructors and staff.

2. Cost of support rendered to the institution (including pay and allowances of personnel) by TOE units whose mission is to support the institution (Program 8T).

3. Student pay and allowances.

4. Student travel pay to the institution.

5. Cost of ammunition expended for institutional training.

6. Student per diem entitlements at the institution.

7. Depreciation of equipment dedicated to institutional training.

8. Cost of consumable supplies and material.

9. Cost of contractual services.

10. Institutional overhead costs such as the pay and allowances of personnel in offices of the Commandant, Security, Director of Logistics and of School Training Brigades.

Indirect costs of institutional training are those costs not directly and wholly attributable to training but all, or at least part, of which should be charged to training. These costs include:

1. Cost of support rendered to the institution by Program 2 TOE units. Military pay, operations and maintenance, and TOE equipment depreciation are apportioned according to the man-days of support rendered. It is recognized that these units are in the force structure to meet Joint Chiefs of Staff requirements and that pay and allowances, for example, would be a cost whether or not they support institutional training. However, time diverted to support institutional training should be accounted for -- especially when comparing systems. This may be done by converting this time to dollars. Additionally, using pay and allowances to do this permits consideration of the different grades of personnel required by competing systems.

2. Proportionate share of the costs of base operations, family housing administration, base communications, base medical support.

The cost of initial proficiency training that takes place in Program 2 units is somewhat more complex. The number of hours the unit devotes to individual training on a particular system can be estimated from careful study of the unit's training schedule. A pro rata share of the unit's annual costs of the following should be included:

1. Spare parts. Rather than using the moment of equipment failure or repair as the basis for attributing total repair costs, it would be more accurate to charge a pro rata share to training based on the fraction of the use time allotted to training or, if known, the fraction of the mileage attributable to training, in the case of vehicles.

2. POL.

3. Ammunition expended for training on the system. This can probably be accounted for accurately without using the pro rata distribution (except for costing by task).

4. Military pay and allowances -- again based on the previous discussion concerning converting to dollars the time diverted from primary mission.

5. Construction of special ranges or training facilities (e.g., Redeye Moving Target Simulator (MTS)) for training on the particular system. Here, it is important to cost only the proportion of costs attributable to initial proficiency training.

6. Acquisition costs of training devices charged to the unit and specifically for training the particular system.

7. Operation and maintenance of training devices pertaining to the system being studied. These may be costs incurred by the Training Aids Service Center (TASC).

Costs may be divided further into variable costs and fixed costs. Variable costs as used herein are, in general, those that vary with changes in the training load. Thus they can be used to estimate the changes in total cost as the training load changes. Fixed costs, on the other hand, are, within certain limits, insensitive to changes in the training load. Support by Program 8T TOE units and equipment depreciation are examples of fixed costs. Ammunition expenditures, student pay and allowances, travel pay, and per diem are examples of variable costs.

The Litton equations constitute the cost model for initial training of a system. The equations are patterned after but extend those developed by the Training Analysis and Evaluation Group (TAEG) of the U. S. Navy and reported in TAEG Report Number 16, "A Technique for Choosing Cost-Effective Instructional

Delivery Systems," April 1975. The Litton model employs FORTRAN representation for the names of the cost factors. The names and definitions are intentionally close to the parallel factors employed by TAEG. The basic input variable selection philosophy, also similar to TAEG, employs five generic categories of cost factors:

1. Facilities

2. Equipment

3. Instructional Materials

4. Personnel

5. Miscellaneous

There are significant differences between the two models. The Litton model expands TECEP coverage of institutional training costs to include inter alia institutional field training costs. The Litton model also adds cost factors for the individual and collective initial proficiency training done in Program 2 (force) units. Thus, a number of TECEP's input variables have been omitted, and new variables have been introduced into the Litton model.

The Litton model is based on certain assumptions. Some of these are discussed in the explanation of the cost equations, presented in the User's Guide that accompanies this report (Cost and Training Effectiveness Analysis Performance Guide).

The Litton model assumes:

1. Individual training beyond initial proficiency on the system is not included. Thus, refresher training is omitted.

2. Unit effectiveness training beyond initial operational capability is not included.

3. Costs associated with loss of life, property, or time occasioned by accidents are excluded.

More detailed assumptions, equations, and examples of use of the model are presented in the CTEA Performance Guide published as a companion to this report.

SECTION V

SYNTHESIS OF CTEA METHODS

The LCSMM has been examined to determine the requirements for and purposes of CTEA. This examination resulted in the identification of probable CTEA locations in the LCSMM. Methods applicable to CTEA have been identified through a literature review and new methods have been devised to fill gaps in methodology.

The CTEA methods identified through the literature review and those developed to meet recognized needs have been analyzed to reveal their embedded processes. The analysis was based on a general CTEA model that identifies necessary CTEA processes and thus points to a set of input-data situations and to a taxonomy of CTEA process methods. The general model and taxonomy produce a synthesis of methods that better meet the needs and conditions of the acquisition process than any single method.

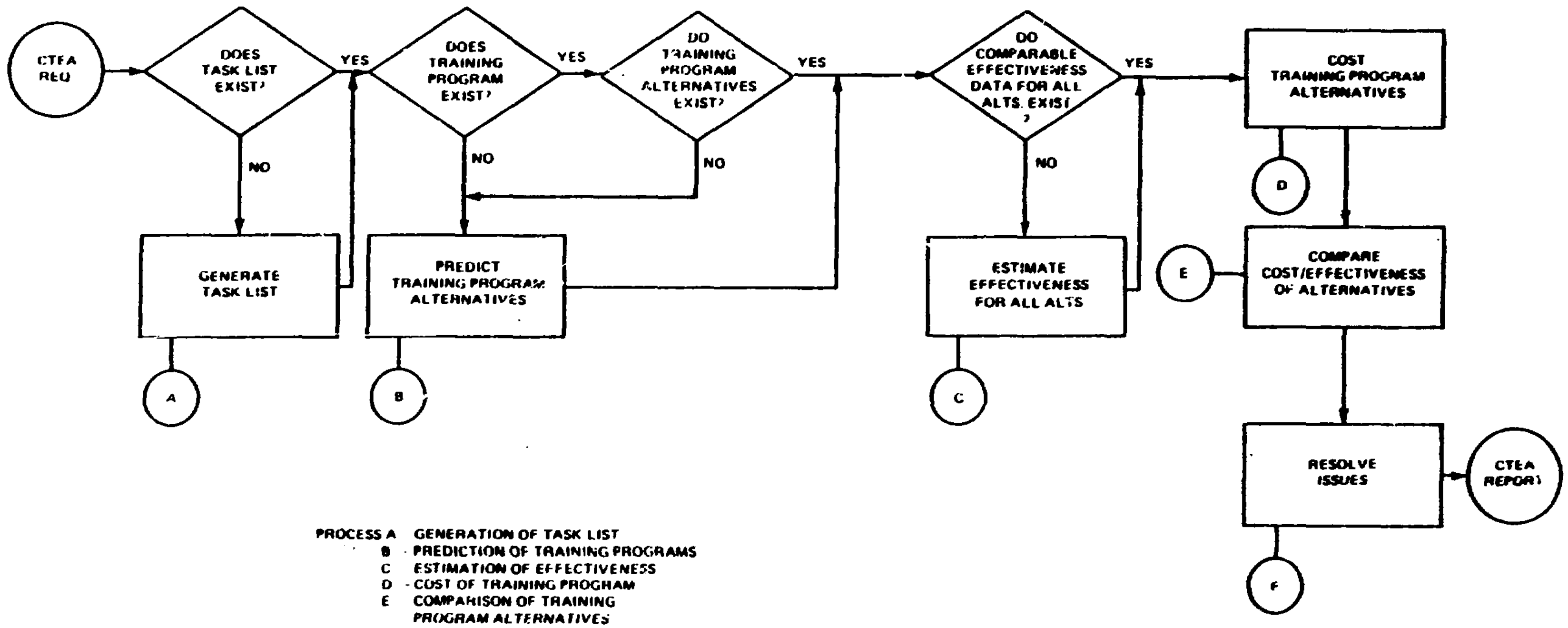
A. The General CTEA Model

The selection of CTEA methods in the LCSMM is controlled primarily by the available data and the issues to be resolved by the CTEA. Method selection begins with the identification of the basic analytical processes made necessary by the relative sparseness or richness of the data and then proceeds to the selection of ways to accomplish those processes. After these initial selections, the means of addressing the specific issues and questions of the CTEA are considered.

This approach to the selection of CTEA methods is illustrated in Figure V-1. The analyst first asks whether a training program actually exists. The program, including tasks to be trained, methods to train tasks, personnel to be trained, locations of training for various tasks, etc. may be in the form of a training description not yet actualized or in the form of an ongoing training activity.

Depending on the answer to this question, the analysis proceeds along one of two primary tracks. If there is no training program, the analyst next determines whether there is a task list complete enough to permit predictions or estimations of alternative training programs. If there is no such task list, or if it is not complete enough to permit the prediction or estimation of alternative training programs, he/she selects methods for the accomplishment of the task-generation process. Once a task list has been generated, or it has been established that a complete enough task list exists, he/she selects methods for the training-prediction process. After selection of such methods, methods are selected for the remaining processes: estimation of effectiveness, costing of training program alternatives, cost effectiveness comparisons of training program alternatives, and resolution of issues.

If there is a training program, the analysis proceeds along the other primary track. In this event, the second question concerns the existence of training program alternatives. If there are no alternatives the analyst decides how to predict or estimate alternatives and how then to estimate their effectiveness. Once it has been established that alternatives do exist or methods have been



PROCESS A GENERATION OF TASK LIST
B PREDICTION OF TRAINING PROGRAMS
C ESTIMATION OF EFFECTIVENESS
D COST OF TRAINING PROGRAM
E COMPARISON OF TRAINING PROGRAM ALTERNATIVES
F RESOLUTION OF ISSUES

Figure V-1. General CTEA Model

selected for the prediction of alternatives and the estimations of their effectiveness, the analyst next determines if comparable effectiveness data for all alternatives exist. If there are no such comparable effectiveness data for all alternatives (i.e., comparable performance measurements for all alternatives or comparable estimates of effectiveness for all alternatives), then the effectiveness of alternatives for which there are no data or performance measures are estimated. This requirement is based on the assumption that, even when one or more alternatives are actual training activities, the analyst will not be able to obtain performance measures for the current CTEA by requesting the administrations of tests and that effectiveness comparisons of alternatives must therefore include comparions of estimated effectiveness. Once it has been determined that comparable effectiveness data for all alternatives exist, or methods for estimating the effectiveness of all alternatives have been selected, the analyst selects methods for the remaining processes: cost analysis of training program alternatives, cost/effectiveness comparisons of training program alternatives, and resolutions of issues.

The six basic input-data situations in the general model are:

1. No Task List and No Training Program. In the worst case, function and job analyses have not been conducted or are not available to the CTEA analyst. Task lists and training programs need to be estimated in order conduct the CTEA.

2. Task List but No Training Program. If function and job analyses have been completed but no training program has been designed, the training program needs to be estimated or predicted for use in the CTEA. If the task list is very rudimentary (i.e., does not contain complete task statements) then the analyst needs to use a method for estimating the training program that is not overly sensitive to gross task information. A training program can be estimated and analyzed from a rudimentary task list but the result will be a rudimentary estimate. Since training development is iterated during acquisition, however, a rudimentary estimate is adequate for a CTEA early in the LCSMM. CTEA methods used with early, rudimentary data need to be robust in the face of vague, incomplete, and inaccurate task information.

If this situation occurs in the demonstration and validation phase or later, precise task information is highly desirable. Some task and training data may be available from the manufacturer, who develops and implements training for DT/OT I. Task information may be available although a training program may not be available in printed form. The CTEA analyst can predict a training program based on the refined task information and the predicted program is a reasonable estimate; thus, CTEA estimates based on the predicted training are also reasonable.

3. Training Program but No Alternatives and No Effectveness Data. The training program implies the existence of a detailed task list that may contain complete task statements. The earliest training program is likely to be the one produced by the manufacturer although it may be a service school product. Since there are no alternative training programs, the relative merits and costs of the extant program have not been estimated.

4. Training Program with Effectiveness Data but No Alternatives. In this instance there may be a detailed, complete task list. The training program is likely to be that produced by the manufacturer, and the effectiveness data are

likely to be those from DT/OT I. These data are likely to be anecdotal and may not be reported since training evaluation is not a requisite in that test. The effectiveness data may be expert estimates or judgments. Since there are no alternative training programs, there are no comparative estimates of cost or effectiveness.

5. Alternate Training Programs but No Effectiveness Data for All Alternatives. The programs are likely to be those produced by the manufacturer and by the service school. One or more may have effectiveness data of some sort while others do not. For example, the manufacturer's training program may be tested in DT/OT I while the service school program remains untested. Effectiveness data for one or more programs need to be produced, perhaps by estimation, if all alternatives are to be compared for relative effectiveness and cost.

6. Training Program Alternatives and Effectiveness Data for All Alternatives. This situation implies a fully developed task list. One or more training programs may have been tested to yield performance measures, and the programs may have been tested in other research. The effectiveness measures may differ in type and in whether they are empirical or judgmental. This situation is likely if the training programs were tested in DT/OT II during the full-scale development phase of the LCSMM.

The general CTEA model thus identifies the total set of required CTEA processes and relates these processes to specific CTEA as defined by their input data. Because each process may be carried out by means of a variety of possible methods, each process suggests a category of a taxonomic scheme through which those methods may be analyzed to reveal their embedded processes.

B. A Taxonomy of CTEA Processes

All of the CTEA-applicable methods reviewed and those devised by Litton have been analyzed to determine the methods through which the required CTEA processes have been or may be carried out. In Table V-1 the required general CTEA processes are arranged along one dimension while the various CTEA-applicable methods are arranged along the other. Each column constitutes a class of processes in which each method, depending on data conditions and other factors, may be employed to carry out the process identified. Rows display the general applicability of methods to CTEA.

Table V-1 shows how the various CTEA and CTEA-related methods fit the requirements of the general CTEA model. Unmet needs are also revealed. The one presently available automated cost model, the Navy's TECEP cost model, does not cover the costs of institutional field training or of unit training. Available process methods for the prediction of training programs do not include a formal method for predicting the training of new tasks from the established (and thus validated) training of similar existing tasks; without such a method there can be no formal application of the accumulated knowledge of how tasks of various types can be effectively trained. Finally, there are no methods for resolving the issue of trainability. How, for example, does the analyst determine that a task may not be trainable or may pose such a training risk that operational effectiveness may be jeopardized? Litton's trainability analysis is offered as an interim process until trainability is more thoroughly explored.

TABLE V-1. REQUIRED ANALYTICAL PROCESSES AND CANDIDATE METHODS

	REQUIRED ANALYTICAL PROCESSES					
	A GENERATION OF TASK LIST	B PREDICTION OF TRAINING PROGRAMS	C ESTIMATION OF EFFECTIVENESS	D COSTING OF TRAINING PROGRAMS	E COMPARISON OF TRAINING PROGRAM ALTERNATIVES	F RESOLUTION OF ISSUES
CANDIDATE METHODS	DIVAD GUN HAWK PIP ROLAND	TEEM TECEP DIVAD GUN ATM	TEEM DIVAD GUN ATM TRAINVICE TCA	LITTON COST MODEL	TEEM TCA BDM/CARAF DIVAD GUN DRIMS ATM TECEP	ITV DRIMS TRAINABILITY ANALYSIS

C. CTEA Situations and Strategies: A Synthesis of Processes

The general CTEA model and taxonomy describe a variety of possible CTEA situations differing in input information and issues addressed. The situations correspond roughly to the phases of the LCSMM but do not correspond exactly because systems do not progress through the acquisition cycle in lock-step manner. Potential input information includes task lists, training programs, and effectiveness data. In some cases the data may exist but may not be available to the CTEA analyst and cannot be applied in the analysis.

The final challenge in the synthesis of CTEA methods was to devise general plans or strategies to guide the selection of processes required in the input-data situations. Each situation identifies a set of required processes and suggests an approach to meet the CTEA objectives.

1. Generation of Task List

CTEA require knowledge of what is to be trained, but those conducted early in the acquisition process may not have access to such knowledge, at least not in the form of task lists. In this case an initial effort within the CTEA must be to generate task lists. Such task lists need not be as detailed as the formal task descriptions that will eventually be developed (for such documents as the Soldier's Manual), but they should be detailed and comprehensive enough to permit a reasonably reliable estimation (or prediction) of the training program that will support the tasks. But even when only the most general task information can be obtained, training programs can be at least tentatively estimated.

The person responsible for an early CTEA may encounter data availability conditions that range from no task list at all to existing formal task lists. The worst case occurs when there is general information about the new system but there are no TASA data. If a formal task list is available the analyst proceeds to the next strategy and starts with training generation.

a. The Army has developed these methods for generating task lists on the basis of subject-matter expertise:

(1) <u>DIVAD Gun CTEA Process for Generation of Task List</u>. If there are no TASA data, but general information about the new system and its training devices and detailed knowledge about similar systems is available, the "generic CTEA" processes used for the DIVAD Gun apply. Training program alternatives are predicted on the basis of the established training practices of existing systems of the same class and knowledge of the new system and its training devices. The steps are:

o Analyze descriptions of new system and place new system in class of similar systems.

o Identify generic tasks of class of systems. (These are tasks or task types that tend to be common to all systems of the class.)

o On the basis of general knowledge of new systems and its training devices, revise generic task list to make it as specific as possible to new system.

A task list generated in this manner is used to estimate effectiveness of alternatives rather than to predict them; the alternatives are based on training practices of the class of weapon systems.

(2) <u>Hawk Product Improvement Program (PIP) Training Development</u>. This process is applicable if there are no TASA data but tasks are inferred from the contractor's draft technical manual and from detailed knowledge about the antecedent system. It was applied to the generation of task lists for a PIP and may be limited to those situations. The steps are:

o Secure task lists of antecedent system.

o Analyze technical documentation (draft TM) and compare with task lists of antecedent system.

o Revise (or add to) task lists of antecedent system to make them consistent with technical documentation of new (or modified) system.

It may be necessary or desirable to develop some new tasks through trial performance on new equipment.

(3) <u>Roland Training Development</u>. The Roland training development process is applicable if there are TASA data and descriptions of personnel functions in the technical documentation, but no formal lists of tasks. It assumes that detailed knowledge of the antecedent system is available. This process represents a considerably higher level of analysis than the previous two processes, and the prediction of training programs may therefore be more precise. It identifies critical tasks and selects training sites. It does, however, require an analyst who is a subject-matter expert with experience and training on the system since precise judgments are required. The steps are:

o Secure contractor's (manufacturer's) LSAR D sheets and draft TM.

o Compare tasks in LSAR with descriptions in TM and revise to make consistent with LSAR, TM, and analyst's expert judgment.

o List tasks on Task Selection Worksheet.

b. <u>Strategy for CTEA Lacking Task Lists</u>. When there is no task list the analyst must perform all processes from generation of the task list to resolution of issues. In this situation the analyst uses expert judgment to generate the task lists, therefore the analyst is also likely to use expert judgment for prediction of alternative training programs and estimation of training effectiveness. Formal analytical methods also can be used to predict the training programs and then also used to estimate the effectiveness. The estimates for effectiveness need to be in the same terms, i.e., produced by the same method, to be comparable. Similarly, cost estimates for comparisons need to be in the same terms.

2. Prediction of Training Programs

When there is a task list but no training program the analyst proceeds with the production of alternative training programs. Prediction of training

programs is accomplished in several ways. First is expert knowledge of the materiel system or expert knowledge of the class of weapons. Training programs estimated early in the LCSMM need not be as precise as those estimated later. Analytical methods such as TEEM, TECEP, and the Analogous Task Method predict alternative training programs.

a. These methods are recommended in particular if there is one training program already designed but there are no alternative programs because these methods are recommended for the comparison of alternative training programs.

(1) TEEM Process for Predicting Training Programs. TEEM predicts training programs by describing both tasks and certain elements of training programs in terms of the same set of variables, called a "metalanguage." The variables, or metalanguage, were identified through a literature search and generally represent research findings concerning relationships between task condition or requirements and various types of instructional media and methods. Variables relating task conditions or requirements to content and content structure have also been tentatively identified, but these are not yet employed in the processes of the method.

Tasks are first described in terms of variables classified as stimulus variables, response variables, and feedback variables. They are then logically grouped so that media selection may proceed. Each task results in the selection of one or more media devices or forms ideally suited to that task, but the total set of such devices or forms is reduced in response to real-world constraints so that only a few media devices or forms serve all tasks. The functional contexts of task groups are similarily described in terms of method variables (these relate task contexts to instructional methods), and instructional methods are thus selected.

The input of this training-program-prediction process is task information in various formats from which at least nouns, verbs, and modifiers descriptive of the task may be derived. Briefly, the task information must indicate what is done to what within what limits or under what conditions. The output is a set of media and instructional methods. Further development of the method may result in the inclusion of specifications for content and content structure.

(2) TECEP Process for Predicting Training Programs. TECEP predicts training programs in terms of suitable instructional algorithms and delivery systems. Each task or training objective of a training program is matched with one of 12 learning algorithms. The matching is accomplished by comparing the statement of the task or training objective, including the verbs, with the lists of action verbs, behavioral attributes, and examples of training objectives included in the algorithm charts. Once each task has been matched with an algorithm, all tasks are grouped or classified according to the algorithm selected for it. Then, two or more types of delivery systems are selected for each group of tasks. Such delivery systems are to be considered only candidates for the developing training program, however, and must survive tests of practicality and other constraints.

(3) DIVAD Gun Process for Predicting Training Programs. This process method might be termed the "worst-case method" for the prediction of

training program alternatives. Training program alternatives are formulated on the basis of established training practices within the class of weapon systems (or other materiel systems) to which the developing system belongs. Alternatives are likely to consist of different arrangements of operational equipment and various training devices (simulators, etc.).

(4) Analogous Task Method for Predicting Training Programs. Tasks of fielded systems that are analogous to the tasks for which training programs are being predicted (target tasks) are identified. Once it has been verified that an analogous task is similar enough to the target task to permit the inference that the same training program would be effective in training both tasks, the training program of the analogous task becomes, in effect, the training program of the target task.

b. Strategies for CTEA Using Predicted Training Programs. Training programs may be estimated by informal judgment or by formal analytical methods such as TEEM, TECEP, and ATM. The formal analytical methods are recommended to predict training program alternatives to be compared with either those predicted by expert judgment or with existing training programs. Large differences in the training programs predicted by divergent methods signal areas that require closer attention.

If at least one training program has been predicted, informal expert knowledge is not recommended for prediction of alternatives. Since the tasks are known, the formal analytic methods can be employed. Whatever the method employed, different levels of training devices and media are estimated for comparison with the devices and media in the existing program.

3. Estimation of Training Effectiveness

Ideally, effectiveness is determined empirically, but because of the impossibility of obtaining direct empirical data for systems not yet developed to the prototype stage and the difficulties in obtaining it even for systems in prototype or later stages, estimation is often necessary.

a. Three kinds of methods for the estimation of effectiveness appear to be possible: analysis of how well a proposed training program "fits" the tasks to be trained; expert judgments about the relative effectiveness of a set of proposed programs; and generalization of the demonstrated effectiveness of the training program of one task to the training program of all nearly identical (analogous) tasks.

(1) TEEM Process for Estimating Effectiveness. In this method an efficiency metric that expresses how well a training program "fits" the tasks to be trained is taken as an estimate of effectiveness. The metric is the ratio of measures, derived from the media selection processes, of constrained, real-world programs and unconstrained, ideal programs. That is, each task results in the initial selection of a media type ideal for that task, but then tasks are logically grouped and the total set of media is reduced to an average, compromised media selection for each functional task group or training situation, simply because real-world constraints would not permit the costly and possibly unmanageable ideal. Thus, the measures or scores associated with the selection of the constrained, real-world set of media are divided by the measures

or scores associated with unconstrained, ideal set of media to produce an "efficiency" ratio. The assumption is that if a training program were totally unconstrained in the selection of media, then the media type selected for each task would be ideal for that task and the effectiveness of the training would be greater than if the program were constrained and media selections were less than ideally suited to each task.

(2) DIVAD Gun CTEA Process for Estimating Effectiveness. This process method for the estimation of effectiveness cannot be described in detail because of a lack of information, but it was clearly informal as applied in the DIVAD Gun CTEA. One or more analysts, experts on the class of weapons to which the DIVAD gun belongs, examined the proposed alternatives in light of their knowledge of the "generic" tasks of the class of weapons and much knowledge as they had of the DIVAD Gun and the ranked them on the basis of judged effectiveness.

(3) Analogous Task Method for Estimating Effectiveness. Tasks of fielded systems that are analogous to the tasks for which training programs are being predicted (target tasks) are first identified. The training prgrams of the analogous tasks are adopted as the training programs of the target tasks, and the empirical effectiveness data of the analogous tasks become estimates of the effectiveness of the analogous task training program applied to the target tasks.

(4) TRAINVICE Method for Estimating Effectiveness. To estimate the effectiveness or proposed training device alternatives, the CTEA analyst applies the TRAINVICE procedures for the following analyses:

- Task commonality
- Physical similarity
- Functional similarity
- Learning deficit
- Training techniques

For each subtask to be trained by a device these yield an estimate of device effectiveness, and the separate estimates are then combined to yield an overall estimate of device effectiveness. (According to Training Device Requirements Documents Guide, DARCOM provides cost estimates for training devices though the device project office of the proponent school. DTD may be required to provide some cost data. It is also important to note that, since there is not yet a way to combine the effectiveness estimation metrics of both training devices and training programs to yield a single metric as an estimate of the effectiveness of a training program with a training device, the estimation of the effectiveness of training devices and the estimation of the effectiveness of training programs must be considered as separate issues. Once the most effective training device alternatives have been selected, however, it may be considered within the context of training program alternatives as the costs and effectiveness of these alternatives are estimated. Given the characteristics of the most effective training device alternatives, TCA, for example, could be used to estimate the relative effectiveness of training programs with and without the device.)

(5) TCA Process for Estimating Effectiveness. In TCA the estimate of effectiveness is the Training Consonar Ratio (TCR). Tasks are described in terms of 85 psychological variables a .ien each combination of medium and methoa is described in terms of the same 85 variables. The goodness-of-fit between the task descriptions and the descriptions of the combinations of me and methods used to train the tasks is expressed in terms of the Training Consonance Ratio. The TCR is almost exactly analogous to the efficiency ratio of TEEM since the same lists of variables are used in essentially the same way.

b. Strategies for Estimation of Training Effectiveness. If there are alternative training programs but not all of the programs have effectiveness data, the analyst starts with effectiveness estimation.

It is reasonable to apply expert judgment to estimate effectiveness of training programs that were predicted by expert judgment. If a task is similar to a task in an existing system about which the analyst has knowledge, and if it is known that a certain type of training results in the required level of proficiency on that task, then that training approach can be estimated for the new training program.

If the analogous task method, a formal analytic procedure, was used to predict a training program, then it is also used to estimate the training effectiveness of the program. If TEEM was used to estimate two or more training alternatives, the TEEM efficiency ratio is the estimate of effectiveness. Training consonance analysis (TCA) can be used to estimate effectiveness no matter how the programs were predicted: the training consonance ratios produced by TCA are the effectiveness estimates. TCA estimates effectiveness of both existing and predicted programs. It also diagnoses training deficiencies, excesses, and redundancies for revision.

The state of the task information (e.g., very rudimentary, refined, or fully developed) determines the precision of training program estimation and training effectiveness estimation. Within a comparison, the levels of information concerning training effectiveness must be common for them to be comparable.

4. Cost Analysis of Training Programs

The estimation of the costs of training programs is a complex process involving many variables, but estimation must be precise as possible since cost effective decisions about competing alternatives are to be made. The one cost process method selected for inclusion in the manual appears to offer the possibilitiy of accurate cost analysis along with a reasonable approach to the complexity of the costing problem.

a. Litton Cost Model. The Litton cost model is a modification of the TECEP cost model. It expands the coverage of training costs to include both institutional field training and initial proficiency training in the units, and it should therefore provide more precise analysis of training costs than TECEP cost model. Because it is computerized the complexity of the problem from the analyst's point of view is somewhat lessened. The Litton cost model is intended for cost estimates only, not for budgetary requirements.

b. Strategy for Cost Analysis of Training Programs. The modified TECEP model is recommended for all CTEA situations in the LCSMM. If one training program is estimated by expert judgment, or if one program actually exists, while the others are estimated by using the formal analytic methods, it is important to note that the cost estimates must be comparable in level of detail and precision if valid cost comparisons among alternatives are to be made.

5. Comparison of Alternative Training Programs

Once the effectiveness and costs of competing training program alternatives have been estimated or measured, the alternatives must be compared with each other and with externally imposed standards or criteria. The purpose of the comparison is the selection of the most cost effective of the alternatives which meet the criteria. In order to assure that the conflicting demands of adequate effectiveness and minimal costs are met, some sort of rational scheme or method for comparison must be employed.

In established practice, schemes or methods for comparison range from informal comparisons of rankings of alternatives on both effectiveness and costs to formal cost benefit analyses. Further, because it may be necessary or desirable to consider factors in addition to cost and effectiveness in the selection of a training program, there are methods for incorporating these additional factors in the decision metric.

a. The following process methods by no means represent all possibilities for the comparison of alternatives, but they do represent established methods and provide for the requirements of most CTEA.

(1) TEEM Comparison of Training Alternatives. In this method the estimate of effectiveness, the efficiency ratio, is not a strong one but it is the best available in a very early CTEA. Cost effectiveness (C/E) ratios are formed and compared. The analyst selects the efficiency ratio that represents the lowest acceptable effectiveness and this step is difficult and judgmental. The plot of the series of efficiency ratios (Figure III-7) is closely examined for pronounced decreases in efficiency as a result of the reduction of the media. Efficiency may drop off slowly at first as medium after medium is removed from the training description but then at some point it begins to drop off quite sharply. At this point or sooner the analyst will probably decide that minimal acceptable efficiency has been reached and that the media set can be reduced no further. Then, because the relationship between cost and efficiency (and therefore effectiveness) is not likely to be linear, he/she will choose media sets represented by several points higher than the minimal point and then compare the media sets in terms of cost and efficiency. The alternative with the smallest acceptable C/E value is chosen since it represents an acceptable efficiency (effectiveness) at the lowest cost.

(2) TCA Comparison of Training Alternatives. The estimate of effectiveness in Training Consonance Analysis (TCA) is the Training Consonance Ratio (TCR). The TCR is similar to the efficiency ratio of TEEM, but it is derived for training programs predicted by means other than formal analytic methods. TCRs are derived by comparing task descriptions with training program descriptions. The analyst encodes task descriptions and training program descriptions as input for the TCA computer program, and the computer program

provides output in the form of TCRs and other data including diagnostic information. Training program alternatives (i.e., media sets and methods) are compared as TCRs combined with costs (C/E ratios).

When a predicted training program is being compared with an actual (implemented) training program and the actual program has not demonstrated acceptable effectiveness, the predicted training programs may have both a higher TCR and a lower C/E value. In this case, several approaches are open to the analyst. First, the predicted program could be recommended for replacement of the actual program. Second, the description of the predicted program could be compared task by task with the description of the actual program to form a basis for recommended revisions of the actual training program. Third, the diagnostic information provided by the TCA program (training deficiencies, excesses, and redundancies) could also be used to recommend revisions of the actual training program. The second and third approaches would involve alternatives of training descriptions, recomputations of TCRs and costs, and further comparisons of C/E values.

(3) BDM/CARAF Comparison of Training Alternatives. The essence of this method is the comparison of training program alternatives in terms of multiple measures of training effectiveness (MOTE). Each MOTE selected is weighted according to its perceived importance, and a total weighted effectiveness score (the standard measure of effectiveness) is derived. Costs are then derived or estimated and C/E values compared. The method is suitable only for actual training programs when interval or ratio data are available.

(4) DIVAD Gun Comparison of Training Alternatives. This method is appropriate when the choice in terms of cost and effectiveness is very clear cut. It is actually a very simple version of the DRIMS CTEA Method, but when the choice is obviously very clear cut, it is completely adequate and avoids unnecessary complexity.

(5) DRIMS CTEA Comparison of Training Alternatives. This method of comparison considers factors in addition to cost and effectiveness that may be considered important to the selection of a training program or training program element. While it appears to be most relevant to the selection of a training device (as it was applied in the DRIMS CTEA), it could be applicable to whole training programs as well. Alternatives are ranked on all selection factors, including one or more in addition to cost and effectiveness, and a total ranking score is derived. Selection is based on the total ranking score.

(6) Analogous Task Method Comparison of Training Alternatives. When more than one analogous task is discovered, the effectiveness data associated with the training program of one analogous task is compared with the effectiveness data of the training program of the others. The analogous task training program that is most effective becomes, by inference, the training program of the target task.

(7) TECEP Comparison of Training Alternatives. TECEP processes lead directly to training alternative comparisons. Given the training objectives, TECEP selects learning algorithms and instructional delivery systems. The next step of the TECEP Process (Figure III-5) is estimation of the training system cost, and the final step is selection of a cost-effective training delivery system.

b. Strategies for Comparison of Alternative Training Programs. If some training programs have effectiveness data while others do not, the ones that have effectiveness data are considered separately. Training programs that have performance measures for each task are examined to select those tasks acceptable in cost and effectiveness. The decision is based on the cost effectiveness ratios showing the programs with the lowest values (lowest cost per unit of effectiveness).

Cost effectiveness ratios are the estimated cost divided by the estimated effectiveness. These ratios are used to compare the training programs. Analytic methods such as TEEM indicate which levels are acceptable and which are eliminated. Final selection of a training program is deferred until all issues have been resolved. For example, a training program with a higher cost effectiveness ratio may be desirable because it is more effective in training high-risk tasks.

If the effectiveness data are not performance measures or if they are not based on standards in task and training objectives, the analyst uses Training Consonance Ratios (TCR). TCR provide estimates for comparison of the training programs on the basis of effectiveness and costs. Tentatively the program with the lowest cost/effectiveness ratio is selected. The relationships among the cost/effectiveness ratios are informative. If the TCR of one or more predicted alternatives is higher than the ratio for an existing program, the analyst compares the media and methods of the predicted alternatives task by task with the media and methods of the existing program. Also, the analyst examines the existing and predicted training program diagnostic information. This information indicates revisions of the existing program that will increase its TCR and thus its estimated effectiveness. The values may warrant adoption of one of the predicted alternative programs.

If some training programs exist and the others are estimated, and one or more of the programs has measures based on task and training objectives, the analyst uses the cost/effectiveness ratios differently. The training program or programs having effectiveness measures are compared to the objectives to assess deficiencies. If standards or criteria indicate a deficiency, the existing program is eliminated from selection in its unrevised state. The TCR is computed for the program revised as recommended on the basis of the diagnostic data, and the ratio is evaluated. The lowest cost/effectiveness ratio is selected, with the caveat that the cost estimates for existing and predicted programs may not be comparable. Costs of predicted alternatives must include all development costs while the costs of existing programs include fewer developmental costs or none at all.

If the election is made of an existing program with excesses or redundancies, the TCA diagnostic information is used to recommend revisions and thus increase the cost/effectiveness.

If only some of the alternative training programs have effectiveness data, and the data are performance measures, the TCRs are used to compare all alternatives. If a training program without performance measures has a higher TCR than a program with performance measures, that program may be more effective than the program with measures. The analyst might recommend collection of empirical data to verify the effectiveness. If the measures of performance include more than one measure of training effectiveness, the analyst

can use BDM/CARAF to compute a total weighted effectiveness score and use that score to form a cost effectiveness ratio.

When there are training program alternatives and data for all alternatives, the first step is to eliminate from consideration any alternatives that have unacceptable effectiveness. TCRs can be used to diagnose problems and recommend revisions. The acceptable programs are then compared in cost/effectiveness. Programs with the lowest values are selected. If factors other than performance measures are to be considered, the analyst uses the DRIMS CTEA method.

Though the purpose of comparison is to select the most cost effective program, a CTEA may conclude with the recommendation that final selection be deferred until certain issues are resolved through further investigations. Such investigations typically involve experimental determinations of the effects on proficiency of training program alternatives.

6. Resolution of Issues

Most CTEA issues are resolved through processes from the generation of task lists to the comparison of alternative training programs. Still, some will not be resolved by these processes, and special methods for their resolution must be selected or developed.

a. The typical issues requiring special methods are:

(1) Trainability. The issue of trainability requires that tasks and training programs be compared with personnel characteristics to determine if the personnel who are to man a system can be satisfactorily trained to man it through proposed or actual training programs. According to a TRADOC official (Telephone Interview, 25 June 1980) precise methodology in this area is now practically nonexistent but under development. This official endorsed the trainability analysis proposed by Litton (see Section IVB) as a satisfactory stopgap until more precise methods are developed.

(2) Training Device Requirements. Several of the methods tested above address training devices as elements of training programs, but none considers simulators or similar training devices on the basis of the several kinds of fidelity. Because of the large number of uncertainties in the specifications of training devices and the incomplete development of methods for resolutions of training device questions, this issue is considerd to be suitable work for a behavioral scientist rather than the typical CTEA analyst, and no training device analysis method has been selected or recommended.

(3) Performance Versus Standards. This issue will be resolved through the first five processes if complete task statements are available or generated, but the development of standards is a lengthy and difficult process usually requiring threat analysis and therefore does not appear to be a suitable undertaking for the typical CTEA analyst. No methods beyond those included under Process A have been selected or included in the manual.

(4) Performance Versus Hardware. This issue is an aspect of the trainability issue. If one or more tasks are found or estimated to be untrainable, the problem may be attributed to the hardware (faults in design, extremely

difficult tasks for personnel regardless of characteristics, etc.), but no particular method for the resolution of this issue has been selected or included in the manual.

(5) Performance Versus Personnel Selection. This issue, too, is an aspect of th trainability issue. It may be that one or more tasks found or estimated to l untrainable given one set of personnel characteristics may indeed be traina..e given another set of personnel characteristics. Because of the undeveloped state of methodology in this area, no particular method for considering personnel selection within a CTEA has been selected or included in the manual.

(6) Other Possible Issues. These include such issues as user acceptance of a training device, least-cost location of training program, and the extent of or impact of skill decay.

b. Methods that assist in the resolution of the issues are:

(1) ITV CTEA. The ITV CTEA resolved the issue of training location (e.g., which Army training center) through cost comparisons of various locations. Then, under an equal-effectiveness-of-alternatives assumption, alternatives are compared and a selection made on cost alone.

(2) DRIMS CTEA. The DRIMS CTEA resolved the issue of user acceptance by ranking each device and including the ranking in the overall effectiveness assessment.

(3) Trainability Analysis. Task descriptions and training programs are compared with available data on personnel characteristic. On the basis of this informal (subjective) comparison, the analyst rates the risk that a task cannot be adequately trained as (1) high, (2) moderate, or (3) low. Then in the same way tasks are compared with mission analyses or operational concepts and the criticality of each task is judged to be (1) high, (2) moderate, or (3) low. Where high risk-high criticality tasks coincide great concern for trainability is indicated; where moderate risk-moderate criticality tasks coincide moderate concern is indicated; and where low risk-low criticality, high risk-low criticality, or low risk-high criticality tasks coincide little or no concern is indicated (Figure IV-4).

SECTION VI

SUMMARY

Powerful methods applicable to CTEA and the whole manpower, personnel, and training side of acquisition via the LCSMM have been developed and await broad application and refinement. A number of these methods ~~have been~~ are described in Section III.

Existing methods were weak in three areas. First, lack of adequate definition of analogous tasks degraded use of historical data from fielded weapon systems. Second, the issue of trainability (a critical question in the LCSMM) was not adequately addressed. Third, TECEP, the most thorough cost model applicable in the LCSMM, did not address training in Army units. Litton's methods, devised to assist Army analysts in these three areas, ~~have been~~ is presented in Section IV.

Section V describes a general the model for CTEA in the LCSMM. ~~The model~~ queries the data available regardless of the point in the acquisition cycle. It is designed to answer the questions that are pertinent at each stage in the cycle. The model guided selection of methods for use by Army analysts and strategies for application of the methods. The details concerning strategies and procedures are presented in a companion volume, the CTEA Performance Guide.

Methods that include the consolidated data base are especially interesting since they provide a formal informational point of contact for the many agencies involved in an acquisition. When Army acquisitions routinely make use of a consolidated data base, both the timeliness and precision of the analyses will be greatly enhanced. As the various agencies and personnel involved in an acquisition contributed data to and retrieved it from a consolidated data base, they would necessarily become much more aware of the relatedness of the various acquisition processes. While data not yet produced would still not be available, such data as had been produced would be available to all who need it. Another possible benefit of the consolidated data base is that it could encourage all involved in the acqusition process to speak the same technical language, thus increasing the efficiency and precision of communications.

Powerful CTEA and acquisition process methods of the future, if they are realized by the Army, will probably all be computer based. This feature promises not only greatly enhanced efficiency in the processing of information but almost certainly a degree of precision not now achievable. It is possible that such an increase in the efficiency and precision of information processing could both increase the effectiveness of systems and reduce the time required to acquire them.

APPENDIX A

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APPENDIX B

ABSTRACTS OF SELECTED COST OF TRAINING STUDIES

Several documents pertaining to cost analysis of training were reviewed. The documents most relevant to CTEA in the LCSMM were abstracted and the abstracts are presented in this Appendix.

THE ARMY LIFE CYCLE COST MATRIX

(Department of the Army Pamphlets: No. 11-2, "Research and development cost guide for Army materiel Systems," May 1976; "Investment Cost Guide for Army Materiel Systems," April 1976; No. 11-4, "Operating and Support Cost Guide for Army Materiel Systems," April 1976; No. 11-5, "Standards for Presentation and Documentation of Life Cycle Costs Estimates for Army Materiel Systems," May 1976. Washington, DC: Hq, Department of the Army)

In order to encompass all the costs incurred in the life cycle of a weapon system (or major component of the system), the Department of the Army has issued a number of cost guides (DA Pams. 11-2, 11-3, 11-4, and 11-5) for life cycle costing of materiel systems. The cost elements are as shown in Figure B-1, Army Life Cycle Cost Matrix. Although a cost attributable to the requirements for training may be costed in another category, this cost matrix treats training costs as follows:

Category		Budget
1.0	Research and Development	
1.08	Training	RDTE, OMA
2.0	Investment	
2.08	Training	PROC., OMA
3.0	Operating and Support Cost	
3.023	Unit Training, Ammo & Missiles	PROC
3.061	Personnel Replacements	MPA, OMA (depending on focus, assumptions, etc.)

These are further defined by equations (Figs., B-2, B-3, B-4, B-5, B-6). Supporting these equations (a gross, aggregate level) are detailed documentations of each cost element, justifying the dollar figure proposed (for format see Fig. B-7). Although all life cycle costs (LCC) are covered by this matrix, problems remain. A graphic display of the issues is shown in Fig. B-8. Another issue, not shown in the table, is the inability of the analyst specializing in one area to isolate and aggregate all the cost relevant to his particular focus. Training is an outstanding example of such an area. For the purpose of forecasting for complete LCC of training for a given system the analyst must have some cost data, such as ammunition and POL costs, that the weapon system LCC includes as separate categories. The training system cost analyst usually takes the 'bottoms up' costing approach shown in Fig. B-8. This is likely the case when conducting a CTEA for a developing system even though the cost information will be used as input to an analysis conducted by a system cost analyst as required at all major decision points in the acquisition process (usually a formal COEA). This problem was recognized by Hawley and Thomason (1978), developers of an Air Defense CTEA methodology especially fitted within the Army's LCSMM and TSM concepts. Making recommendations for future research, they recognize requirements for:

ARMY LIFE CYCLE COST MATRIX

ROW	FUNDS APPROP	COST ELEMENT NO	COST ELEMENT / SYSTEM STRUCTURE*	(1) [illegible]	(2) [illegible]	(3) [illegible] CONTROL/ COMMUNICATIONS	(4) [illegible] CONTROL	(5) [illegible]	(6) [illegible]	(7) [illegible]	(8) [illegible] SUPPORT EQUIPMENT	(9) [illegible] SUPPORT EQUIPMENT	(10) [illegible]	(11) [illegible]	(12) [illegible]
1		1.0	RESEARCH AND DEVELOPMENT												
2	RDTE	1.01	DEVELOPMENT ENGINEERING												
3	RDTE	1.02	PRODUCIBILITY ENGINEERING AND PLANNING (PEP)												
4	RDTE	1.03	TOOLING												
5	RDTE	1.04	PROTOTYPE MANUFACTURING												
6	RDTE	1.05	DATA												
7	RDTE	1.06	SYSTEM TEST AND EVALUATION												
8	RD/OM	1.07	SYSTEM/PROJECT MANAGEMENT												
9	RD/OM	1.08	TRAINING												
10	RD/MC	1.09	FACILITIES												
11	RDTE	1.10	OTHER												
12		2.0	INVESTMENT												
13	PR/MC	2.01	NON-RECURRING INVESTMENT												
14	PROC	2.02	PRODUCTION												
15	PROC	2.03	ENGINEERING CHANGES												
16	PR/OM	2.04	SYSTEM TEST AND EVALUATION												
17	PR/OM	2.05	DATA												
18	PR/OM	2.06	SYSTEM/PROJECT MANAGEMENT												
19	PR/MC	2.07	OPERATIONAL/SITE ACTIVATION												
20	PR/OM	2.08	TRAINING												
21	PR/OM	2.09	INITIAL SPARES AND REPAIR PARTS												
22	PR/OM	2.10	TRANSPORTATION												
23	PR/OM	2.11	OTHER												
24		3.0	OPERATING AND SUPPORT COST												
25		3.01	MILITARY PERSONNEL												
26	MPA	3.011	CREW PAY AND ALLOWANCES												
27	MPA	3.012	MAINTENANCE PAY AND ALLOWANCES												
28	MPA	3.013	INDIRECT PAY AND ALLOWANCES												
29	MPA	3.014	PERMANENT CHANGE OF STATION												
30		3.02	CONSUMPTION												
31	PR/OM	3.021	REPLENISHMENT SPARES												
32	OMA	3.022	PETROLEUM, OIL AND LUBRICANTS												
33	PROC	3.023	UNIT TRAINING, AMMUNITION AND MISSILES												
34		3.03	DEPOT MAINTENANCE												
35	OMA	3.031	LABOR												
36	PR/OM	3.032	MATERIEL												
37	OMA	3.033	TRANSPORTATION												
38	PROC	3.04	MODIFICATIONS, MATERIEL												
39		3.05	OTHER DIRECT SUPPORT OPERATIONS												
40	OMA	3.051	MAINTENANCE, CIVILIAN LABOR												
41	OMA	3.052	OTHER DIRECT												
42		3.06	INDIRECT SUPPORT OPERATIONS												
43	MP/OM	3.061	PERSONNEL REPLACEMENT												
44	MPA	3.062	TRANSIENTS, PATIENTS AND PRISONERS												
45	OMA	3.063	QUARTERS, MAINTENANCE AND UTILITIES												
46	MP/OM	3.064	MEDICAL SUPPORT												
47	OMA	3.065	OTHER INDIRECT												
48			TOTAL SYSTEM COST (LESS [illegible])												
49	[illegible]	4.0	[illegible] COST												
50			TOTAL SYSTEM COST (WITH [illegible])												

Source: DA Pam 11-2

*THE COLUMN HEADINGS SHOWN ARE GENERAL, USED FOR [illegible] OF SYSTEMS IN GENERAL. FOR SPECIFIC [illegible] SPECIFIC COLUMN HEADINGS ARE THOSE PROVIDED IN APPENDIX A.

**[illegible]

Figure B-1. Army Life Cycle Cost Matrix

RESEARCH AND DEVELOPMENT, 1.0
TRAINING SERVICES AND EQUIPMENT, 1.08

TRAINING SERVICES AND EQUIPMENT 1.08 = (NUMBER OF MAN-YEARS FOR EQUIP DESIGN AND TRAINING) X (AVERAGE COST PER MAN-YEAR)

+ (NUMBER OF TRAINING EQUIP SETS) X (AVERAGE COST PER EQUIP SET)

Source: DA Pam 11–2, p. 6–4

Figure B-2. R&D Training Costs

INVESTMENT, 2.0
TRAINING SERVICES AND EQUIPMENT, 2.08

TRAINING 2.08 = (COST PER MAN-YEAR) X (NUMBER MAN-YEARS CREW AND MAINTENANCE TRAINING INSTRUCTION) + (COST PER EQUIPMENT SET) X (NUMBER EQUIPMENT SETS)

(SPARES COST FACTOR) X (COST PER EQUIPMENT SET) X (NUMBER EQUIPMENT SETS) + (TRAINING FACILITY COST)

(For model representation of cost per man year methodology. See Fig. C–4)

<u>CATEGORIES</u>

PERSONNEL

EQUIPMENT

SPARE PARTS

FACILITY

Source: DA Pam 11–3, p. 6–4

Figure B-3. Investment Training Costs

CONCEPT:

Use a parametric expression based on aggregations of contract pricing type elements. Thus:

COST PER MAN YEAR = (NUMBER MAN-HOURS PER YR) (AVG COST PER MANHOUR) (RATIO OF TOTAL DIRECT TO DIRECT LABOR) (AVG OVERHEAD 1.0 + RATE EXPECTED) (OUT-OF-HOUSE TO 1.0 + IN-HOUSE RATIO) (1.0 + FEE)

NUMBER MAN-HOURS PER YR	AVG COST PER MANHOUR	RATIO OF TOTAL DIRECT TO DIRECT LABOR	AVG OVERHEAD 1.0 + RATE EXPECTED	OUT-OF-HOUSE TO 1.0 + IN-HOUSE RATIO	1.0 + FEE
1960	5.65	1.25	2.25	1.50	1.07
2080 hrs per yr reduced 3 weeks for vacation, sick lv includable in overhead	Avg cost per direct labor hr in FY 71 $ for Investment	This ratio picks up other direct charges beyond direct labor.	This is an aggregate overhead multiplier capturing all burden/G&A expense.	Factors captures materials and sub-contracts awarded during Investment Program. Says for each $1.00 in-house you have 50 cents out-of-house.	This factor captures fee or estimated profit.

Cost = $50,000 (FY 71 $)

NOTE: The overall formulation has the purpose of capturing the essential variables underpinning an aggregate cost factor, cost per Investment manyear. Considerable care and understanding must be excercised in changing one or more of the variables as such variables are highly interrelated and in the case above reflect a mean expectation of cost of a manyear of Investment in any major defense plant. Given the condition of a contractor also performing the role of system manager/integrator, costs of the role of system manager, primilary expressed through the out-of-house ratio, must be eliminated and replaced by the more normal expectation of a small out-of-house contract effort.

Source: DA Pam 11–3, p. 3–3

Figure B-4. Cost Per Man Year Methodology

CONSUMPTION, 3.02
UNIT TRAINING, AMMUNITION AND MISSILES, 3.023

$$\boxed{\begin{matrix}\text{UNIT TNG}\\ \text{AMMO/MSL}\\ \text{3.023}\end{matrix}} = \left(\begin{matrix}\text{TOTAL QUANTITY}\\ \text{OPERATIONAL}\\ \text{EQUIPMENT}\end{matrix}\right) \times \left(\begin{matrix}\text{ANNUAL}\\ \text{AMMO/MSL COST}\\ \text{PER EQUIP}\end{matrix}\right) \times \left(\begin{matrix}\text{NUMBER}\\ \text{OPERATING}\\ \text{YEARS}\end{matrix}\right)$$

Source: DA Pam 11–4, p. 6–3

Figure B-5. Operating Phase, Unit Ammunition Costs

INDIRECT SUPPORT OPERATIONS, 3.06
PERSONNEL REPLACEMENT, 3.061

$$\boxed{\begin{matrix}\text{PERSONNEL}\\ \text{REPLACEMENT}\\ \text{3.061}\end{matrix}} = \left(\begin{matrix}\text{TOTAL QUANTITY}\\ \text{OPERATIONAL}\\ \text{EQUIPMENT}\end{matrix}\right) \times \left(\begin{matrix}\text{TOTAL NUMBER}\\ \text{MILITARY PERS}\\ \text{PER EQUIPMENT}\end{matrix}\right) \times$$

$$\left(\begin{matrix}\text{AVERAGE}\\ \text{ANNUAL}\\ \text{ATTRITION}\\ \text{RATE}\end{matrix}\right) \times \left(\begin{matrix}\text{AVERAGE}\\ \text{REPLACEMENT}\\ \text{COST/MAN}\end{matrix}\right) \times \left(\begin{matrix}\text{NUMBER}\\ \text{OPERATING}\\ \text{YEARS}\end{matrix}\right)$$

Source: DA Pam 11–4, p. 6–7

Figure B-6. Operating Phase, Personnel Replacement Costs

CELL NO: A(3.011.10)
DATE: ________

COST DATA SHEET

ITEM: Crew Pay and Allowance

COST DATA EXPRESSION:

Crew Pay and Allowance – (Total quantity of operational equipment) X (Number of crewmen per equipment) X [(Average annual base P&A per crewman) + (Average annual theater cost per crew) + (Average annual flight pay per crewman)] X (Number of operating years)

INCLUDES:

1. Base pay and allowances, theater cost and flight pay of crew.
2. Subsistence and quarters allowance.

EXCLUDES: PCS Costs

FINAL COST MODEL EXPRESSION:

A(3.011.10) = X1(10) * XN(100) * [AC(44) * AC(45) + AC(46)] * Y1(1) * SF(13)

= 706*2*[13800 + 27 + 2550]*15*1.0 = $347M

VARIABLES ARE:

X1(10) = Total quantity of operational equipment.	=	706
XN(100) = Number of crewmen per equipment.	=	2
AC(44) = Average annual base P&A per crewman.	=	$13,800
AC(45) = Average annual theater cost per crewman.	=	$27
AC(46) = Average annual flight pay per crewman.	=	$2,550
Y1(1) = Number of operating years.	=	15
SF(13) = Constant dollar shift factor for MPA.	=	1.0

VARIABLE NO: AC(44)
CELL NO: ________

VARIABLE EXPLANATION SHEET

ITEM: AC(44), Average Annual Base Pay and Allowance Per Crewman

CURRENT VALUE BEING USED: 13,800 (FY 74 $)

DESCRIPTION OF HOW VALUE DERIVED:

1. The source document for this value ($13,800) is the Army Force Cost Planning Handbook (AFFCPH), Directorate of Cost Analysis, Comptroller of the Army, June 1975.

Source: DA Pam 11–5, p. 4–8

Figure B-7. Documentation Formats Illustrating Documentation of an O&S Cost Element

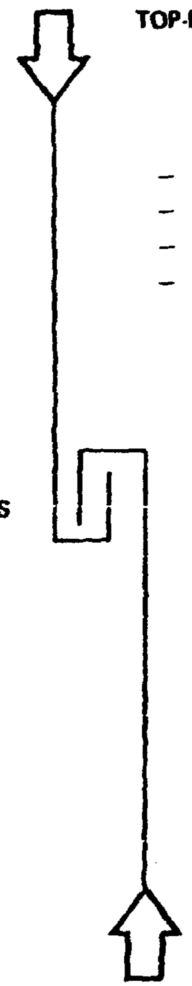
PROBLEM: TO ESTABLISH A STRUCTURE THAT

1. PRESERVES THE USE OF BOTH TOP–DOWN & BOTTOM-UP COSTING APPROACHES
2. PERMITS MANAGEMENT TO AVOID MINUTIA
3. PERMITS ANALYSTS TO UNDERSTAND ISSUES
4. FLOWS AND RELATES DEFINITIONALLY FROM THE AGGREGATE TO THE DISAGGREGATE
5. HAS UNIVERSAL APPLICATION e.g., TO ALL CLASSES OF WEAPON SYSTEMS

TOP-DOWN COSTING APPROACH

- HIGH LEVELS OF COST AGGREGATION
- COSTS STATISTICALLY DERIVED
- OPERATIONS RESEARCH CONVENTIONS
- EMPHASIS: WHAT WE'RE BUYING e.g., SPEED, FIREPOWER, RELIABILITY

A STRUCTURE THAT COUPLES FROM TOP TO BOTTOM



- LOW LEVELS OF COST AGGREGATION
- COSTS DERIVED THROUGH PIECE-PART PRICING
- PROCUREMENT/ACCOUNTING CONVENTIONS
- EMPHASIS: WHAT WE'RE PAYING FOR e.g., LABOR, MATERIALS, OVERHEAD

BOTTOM-UP COSTING APPROACH

Source: DA Pam 11–5, p. B–2.

Figure B-8. A Basic Need In Life Cycle Cost Analysis

1. More definitive work on cost analysis and resource impact projection. A major criticism of the costing model (e.g., TECEP) used in the current demonstration project is that the input cost categories do not match the output categories of the Army's accounting system. Future work should involve a resolution of this problem. The concurrent and predictive validity of costing procedures also has not been established.

2. More work should be done on establishing the organizational links necessary to obtain information concerning RAM, maintenance cost data and maintenance policy information for complex training devices. Equipment RAM and maintenance considerations often underlie assumptions concerning the operating characteristics of the materiel system and the training program. Therefore, the correct estimation of such parameters is essential for valid cost estimation and later sensitivity analyses.

3. The investigation of cost analysis methods providing expected values and confidence limits as output. In CTEA, it would be useful to obtain not only a point estimate of cost, but also a statement of the precision or reliability of the cost point estimate.

(Dept. of Army, "TRADOC Training Effectiveness Analysis Handbook, First Draft" White Sands Missile Range, NM: US Army TRADOC Systems Analysis Activity, undated. Received in 1979)

TRADOC includes CTEA as one type of a family of training effectiveness analysis (TEA). In the recent TRADOC Training Effectiveness Analysis Handbook, First Draft (1979) a CTEA is said to "evaluate the cost and effectiveness of alternative training approaches as they are being formulated to support the developing total hardware oriented system" (p 1-7). The study further specifically defines a CTEA as "a study that assesses the variable effectiveness and variable costs associated with a set of pre-defined alternative training subsystems at each major decision point in the acquisition process." (p 2-2).

This definition forms the basis of the relation of costing to the CTEA methodology. As shown in Fig. B-9, costing is specifically addressed at two points. The first occasion is near the end of the preliminary phase after the concept design of alternative training systems. Estimated concurrently with training subsystems' effectiveness, the cost of each alternative system is input to the decision process that chooses the best alternatives. The second costing effort takes place between OT I and OT II. At this time, a smaller set of 'best alternatives' are selected and alternative training subsystems designed.

This set is costed and their effectiveness assessed and a still more select set chosen and tested in OT II. Costing effort, however, is implied -- either new or revised estimates -- throughout the system and/or training subsystem life. The TRADOC Handbook suggests using the variable cost, variable effectiveness model as the most appropriate for comparing alternative subsystems. They state that the second cost analysis will be more detailed since both training and hardware subsystems are approaching final form making more precise estimates possible.

The cost analysis process is treated in a separate chapter, Chapter 10, Cost Analysis.

The TRADOC-suggested cost methodology is shown in Fig. B-10. It is applicable to both costing 'points'. Cost consideration and data collection are assumed to begin at the front-end analysis.

The generalized cost model is

TTC = ITC + UTC

or

Total training cost = institutional training cost plus unit training cost

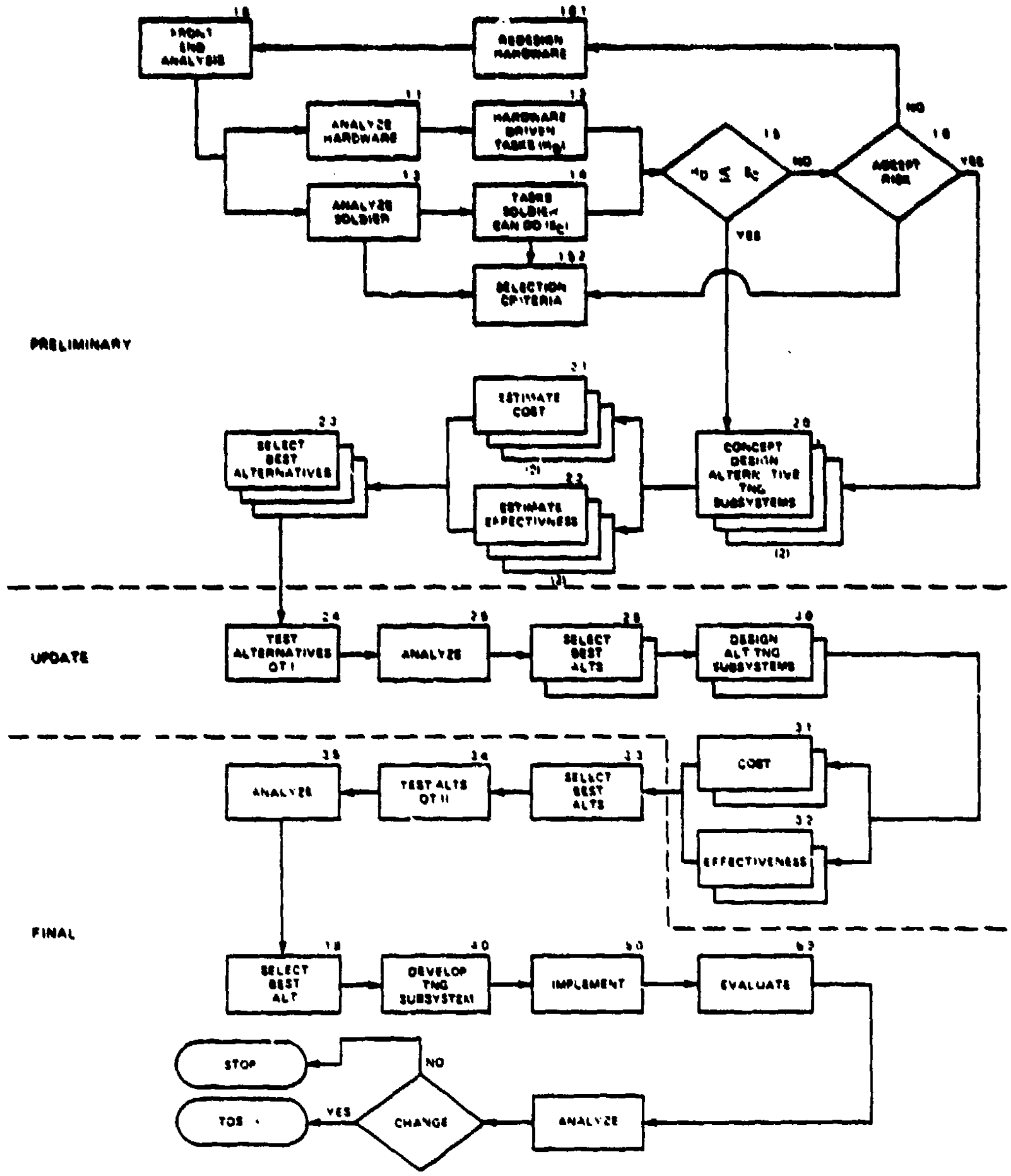
The cost analyst is directed to work with the rest of the study team to define the essential elements of analysis and to identify cost subelements that they require (e.g., ammo, courses, MOS to be trained). Once the TTC of each alternative is calculated, the cost analyst is instructed to highlight in his

analytical presentation subelements of high impact on total cost and those whose incremental or decremental change will influence system effectiveness. Critical cost considerations may outweigh total costs of the alternatives and may be the deciding facors when TTC of the alternatives do not differ significantly. Of further importance, this cost methodology implies that within the basic model, subordinate equations will be written based on the institutional training concepts, the unit training concepts, the training system requirements specification and the life cycle cost estimates. LCC elements (LCCE) are those discussed earlier. TRADOC identifies the LCCE as the primary building block in the cost analysis and the 'only tool' the analyst has to define the hardware costs of the training systems. Suggested sources (Army Agencies) are also listed in Annex I.

Although the list of data for institutional training does not explicitly state that field as well as base (school) training are included, field training and its costs are not precluded and they could be included in such categories as equipment used, etc.

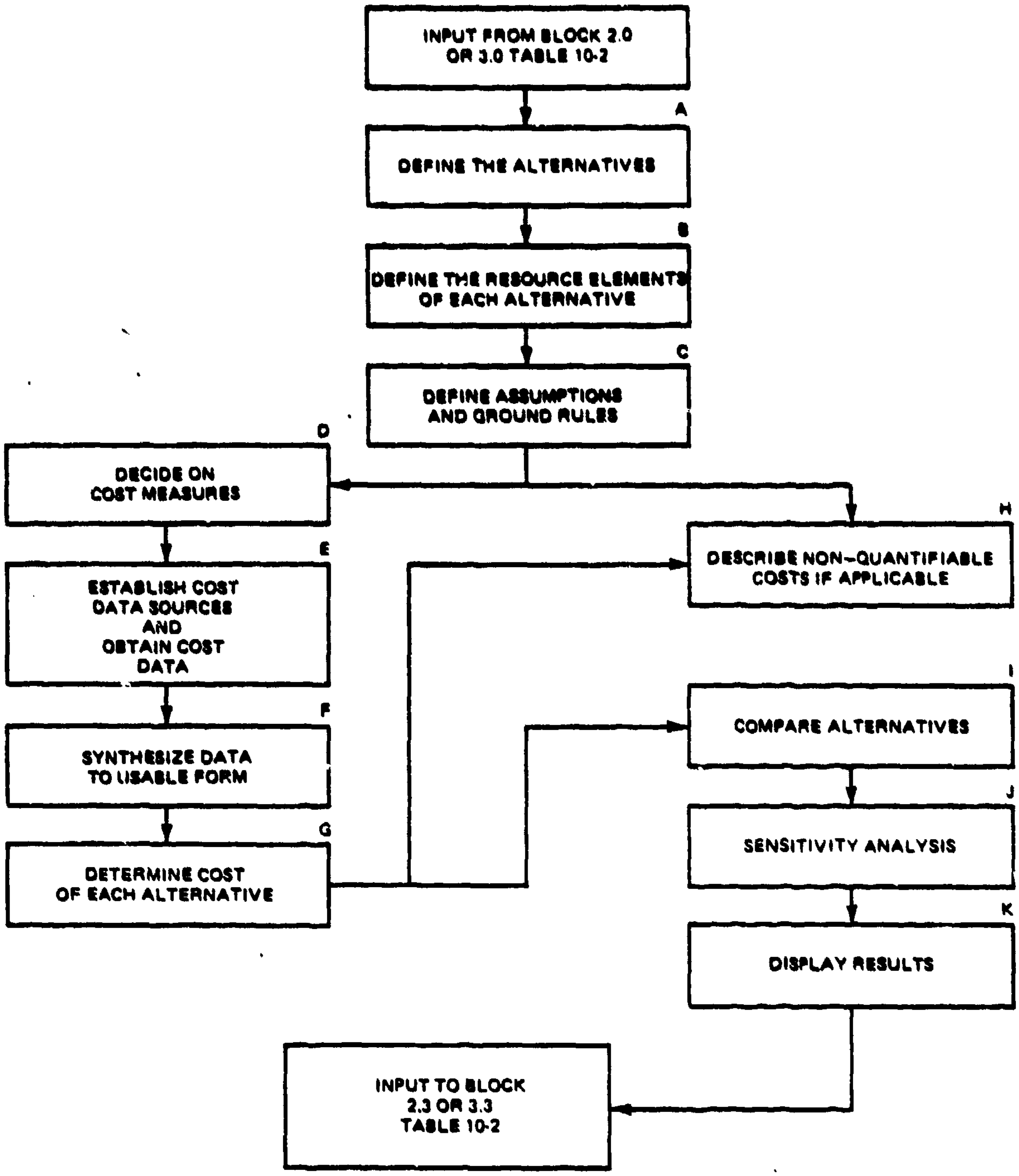
Unit training is examined by 'training event' (e.g., ARTEP events) and the cost of each event over the life of the system accumulated. This should amount to a close approximation of Litton's model for LCC cost. No provision is explicitly stated for prorating costs or evaluating remaining assets at end of costing period.

The TRADOC system rests on identifying critical tasks. The task list, procured from the study proponent and/or contractor or devised by the CTEA analysts, is established in the front-end analysis (Step 1.0, Fig. B-9). This list is used to design the first set of alternative training subsystems but explicit directions for developing a task list are not specified.



Source: TRADOC TEA Handbook, p. 2–8

Figure B-9. CTEA Flowchart



Source: TRADOC TEA Handbook, p. 10–11

Figure B-10. Cost Methodology

SYSTEMS APPROACH TO TRAINING (SAT)/B-1 (1975)

(Ring, W. & Reif, H. B-1 systems approach to training, final report. Appendix A: Cost details, SAT-1, Vol. 2, Wright-Patterson AFB, OH: B-1 Systems Project Office, Data Configuration Division, July 1975)

In 1975 Ring et al. applied the techniques of systems analysis to Instructional System Development (ISD) to ensure that the entire training system is included in Training System Design (TSD). The SAT was used to develop a recommended alternative training system for the future B-1 bomber. A computerized aid to the ISD was used -- the Training Resources Analytic Model (TRAM). TRAM provides time-phased LC costs and resource requirements for the training system of the B-1. The SAT approach provides for trade-offs and sensitivity analyses of such features as ratio of hours spent using various training media, centralization of training facilities, ratio of airborne to ground-based training hours, and training media time phasing. Outputs of the program are descriptions of the recommended and alternative training systems with a syllabus for each course, descriptions of required media and facilities, costs, and schedules.

The initial source of information is considered to be the task analysis data base. The authors state that the quality of this data base establishes the potential quality of the overall instructional system.

The SAT process was applied to the aircrew only. It is not known if maintenance, ground crew or other training, also part of the overall B-1 LCC were similarly analyzed. The task analysis identified 1500 task elements.

The recommended system school setting augmented with training devices and the alternative training systems were all costed. These costed systems were identified by both TRAM and a quick-look version, TROLIE (Training Resources Organized for Logical Integration of Expenses) model runs and subsequent data development.

The cost model was developed to fit a particular segment of the B-1 related personnel -- the four aircrew stations, and three particular training alternatives -- three types of special trainers for each crew station. The data identified as required to cost each of these special trainers by crew station were:

Initial Acquisition Costs

RDT&E and other preproduction costs (includes cost of first unit). These costs were all estimated through application of factors that were percentages of the hardware acquisition cost. For example, initial training = 1.5% of hardware acquisition cost (excluding familiarization trainer).

First unit production costs for trainers. These costs were first determined to lie within ranges and then estimated as a point within the range. For example, the procedures for pilot/copilot station are estimated to fall in a 0.10 - 0.25 (\$ x 10^6) range and estimated to be 0.20 (\$ x 10^6).

General purpose carrels and briefing rooms. These costs were determined to be a function of required multimedia A/V equipment and cost of classroom new construction or conversion. Cost factors such as \$40/sq. ft. for new construction were used.

Facility requirements and costs. A similar costing approach to that of the carrels and briefing rooms was used.

Instructional material. Representative costs for instructional material preparation and production such as viewgraphs at \$10 each; programmed courses, self-paced, at \$600 per instruction hour; and technical data manuals at \$125 per page were used.

Annual Operations and Maintenance Costs

Instructor personnel

Trainee TDY

B-1 Aircraft (direct costs)

Equipment operations and maintenance

Equipment Upgrade

Instructional material

Facilities

All of these costs were estimated using factors for costs and average lead times.

A further feature of this costing effort was the assignment of a data quality designator to each cost element. Costs used were related on a scale of 1-3 depending on the quality (predicted accuracy) of the data source. (See Table B-1 for a list of all elements and quality estimates.) Among the cost data sources were manufacturers; government facilities and simulation users; the Simulation Technology Assessment Report (STAR); the Simulator Special Project Office; commercial handbooks and annuals of A/V and other media and construction costs; and USAF Cost and Planning Factors (AFR 173-10).

A baseline system, three modifications of a part mission trainer (a simulator) alternate baseline concepts, variations in crew ratio and variations in the replacement model were costed.

The foregoing methodology and basic data were used to derive costs used to evaluate, comparatively, the three training systems. Output was formulated to display:

Non-Recurring Costs

RD&E
Acquisition Facilities
Facilities
Instructional Material

Recurring Support

Operation and Maintenance

Costs were displayed as totals by year as appropriate in current dollars for the first year and inflated dollars for succeeding years. Life cycle costs for ten years of operation were costed.

Table B-1. Data Quality Estimates

EQUIPMENT/ACTIVITY	RATING
INITIAL ACQUISITION COST	
COST FACTORS	
RDT&E AND OTHER PREPRODUCTION COST	3
AGE, DATA, OTHER	3
INITIAL TRAINING	3
INITIAL SPARES	3
INTEGRATION AND INTERFACE	3
INSTALLATION AND CHECKOUT	3
PROFIT	2
LEARNING RATE	2
FLIGHT STATION TRAINERS	
FAMILIARIZATION	2
PROCEDURES	2
PART MISSION	2
OSO TRAINERS	
PROCEDURES	2
PART MISSION	2
DSO TRAINERS	
PROCEDURES	3
PART MISSION	3
ANCILLARY EQUIPMENT	
MOTION BASE	1
G SEAT	1
VISUAL DISPLAYS	2
IR	3
OTHER EQUIPMENT	
PROCEDURES TRAINER	2
SUBSYSTEM TRAINER	1
COMPUTER-AIDED INSTRUCTION (CAI)	3
GENERAL PURPOSE CARRELS AND CLASSROOMS	
GENERAL PURPOSE CARRELS	2
CLASSROOMS	2
FACILITY REQUIREMENTS AND COSTS	
REQUIREMENTS (SIZE)	2
COST	2
INSTRUCTIONAL MATERIAL PREPARATION AND PRODUCTION	
LECTURE	3
VISUAL STILLS	1
FILMS	2
AUDIO TAPE	2
AUDIO VISUAL PRESENTATIONS	2
TECHNICAL DATA MANUAL	3
CAI PROGRAM COURSES	3
ANNUAL OPERATIONS AND MAINTENANCE COSTS	
INSTRUCTOR PERSONNEL	1
TDY TRAINEES	1
B-1 AIRCRAFT	2
TRAINER EQUIPMENT	3
EQUIPMENT UPGRADE	3
INSTRUCTIONAL MATERIAL	
MANUALS AND TEXTBOOKS	2
UPGRADE	3
FACILITY MAINTENANCE	2

A TECHNIQUE FOR CHOOSING COST-EFFECTIVE INSTRUCTIONAL DELIVERY SYSTEMS, TAEG REPORT NO. 16 (1975)

(Braby, R., Henry, J.M., Parris, W.F., Jr. & Swope, W.M. A Technique for Choosing Cost-Effective Instructional Delivery Systems, TAEG Rep. No. 16). Orlando, FL. Dept. of the Navy, Training Analysis and Evaluation Group, April 1975)

One of a series of reports prepared for the Navy's Training Analysis and Evaluation Group in Orlando, FL, TAEG Report No. 16 presents a technique for choosing cost-effective delivery systems for proposed training programs. It is not designed as a CTEA methodology although it could be used for conducting one. The researchers (Braby et al., 1975) call the technique TECEP -- training effectiveness, cost effectiveness prediction. It is intended for use by the training system designer during the concept design phase. The methodology includes refinements of two earlier efforts -- one with the same objective (TAEG Report No. 1, 1972) and a technique for choosing cost effective instructional media (1974). TAEG Report No. 16 is designed to be used with two other reports -- TAEG Report No. 23, Learning Guidelines and Algorithms for Twelve Types of Training Objectives and TAEG Report No. 24, Choosing Instructional Delivery Systems with the TECEP Technique.

The report's system development model is earlier shown in Section III, Figure III-5. It requires user expertise (unlike the BDM model designed for CTEA). The position of the TECEP in the TSDM (a continuous, reflexive model) is as shown. A diagram of the TECEP (an input-process-output) model is shown in Figure III-4.

As in other methodologies discussed, the costs are estimated after the instructional systems have been designated. The authors stress the importance of defining study objectives. For example, if the objective is to select the most cost effective alternative from among several choices, the resources common to all in similar amounts can be factored out. When absolute, life-cycle cost is required, then all resources must be included and evaluated at their opportunity cost.

The basic output of the TECEP's cost module is the current cost of each alternative proposed training system. Additional output was (at the time of the study — may now be increased) formatted to show the total and average yearly cost per student position, average cost per course graduate, and a distribution of incidence of cost over the alternative's life.

The designers recognize that it will be necessary to access multiple data sources to apply the cost model. They suggest:

1. past records of operational units

2. NAVPERS personnel data

Model limitations are seen to be: The model cannot select the most efficient media; cannot forecast total system cost; assumes all variable cost functions are linear; does not provide for evaluating secondary effects.

The inputs are divided into seven categories: facilities, equipment, instructional material, personnel, supplies, students, and miscellaneous (36 items in all). This model is computerized, written in FORTRAN IV. The entire output or selected items may be chosen. A maximum 20-year life may be calculated.

TRAINING DEVELOPERS DECISION AID (TDDA) FOR OPTIMIZING PERFORMANCE-BASED TRAINING IN MACHINE ASCENDANT MOS (1978)

(Pieper, W.J., Guard, N.R., Michael, W.T. & Kordek, R.S. Training Developers Decision Aid for Optimizing Performance-Based Training in Machine Ascendant MOS. Valencia, PA: Applied Science Associated, Inc., 1978)

The TDDA is a process for generating training specifications for developers who must decide what, where and how tasks within an MOS must be trained. It was developed in two phases — a manual process model based on logic charts and a computerized model for which the developer inputs task data. Three outputs are available — training prescriptions, training hierarchies and sequences, and training costs. A single assumption, the availability of a usable task list is made.

Cost analysis is the last module. The authors' (Pieper et al., 1978) rationale is that this facilitates identification of beneficial cost trade-offs and permits selection of only the necessary and relevant cost statistics. Training material, course POI, criterion-referenced tests and OJT plans are all considered.

This cost model differs from those previously discussed. Training methods are assigned values derived through a cost rating technique. Pieper et al. chose this method because: (1) actual dollar costs vary over time while relative difference in costs remain essentially constant; (2) ratings can include items such as student time without conversion to dollar amounts; and, (3) the various methods of instruction can be ranked on relevant cost dimensions.

The tasks of any one MOS were treated as a single set -- some taught in schools, some on-the-job, and a few given no formal training. In OJT two factors, number of hours in the learning cycle and number of hours to learn a task, are their determinants. The two-year promotion cycle is set as the learning cycle, with each year treated uniquely and time for training calculated using factors for such items as non-productive duty and movement found in the Army Regulations. This process was recommended for OJT calculation for each MOS.

Training in schools was treated differently. Here Pieper et al. looked at the direct and indirect costs of establishing and operating a resident training facility. They categorized training into seven method cost classes:

Class 1. Conventional classroom, demonstration, case study, and guided discussion.

Class 2. Peer tutor.

Class 3. Tutoring.

Class 4. Programmed instruction (student and program paced), games, in-basket, and study assignment book.

Class 5. Traditional practical exercises.

Class 6. Programmed practical exercise.

Class 7. Computer assisted instruction.

Next, they placed the direct and indirect cost variables into seven classes. These were expected to vary as a result of training method changes. The cost variables used were:

1. Square footage

2. Instructor to student ratio

3. System equipment

4. Furnishings

5. Expendable supplies

6. Training aid development

7. Training material development

Third, the method cost classes were ranked on each of the cost variables. An illustration, Table B-2, shows the method cost classes ranked on one cost variable, value or square footage required for that instructional method. (This is value or benefit not dollar cost.)

Method Cost Class	Sq Ft
1	1
2	3.5
3	3.5
4	3.5
5	6.5
6	6.5
7	3.5

Table B-2

As explained by the authors, "the cost variables were assigned ranks on the basis of their estimated relative values on a scale of one to seven. In the example (Table B-2), the square footage variable for traditional classroom training was assigned a value of one, because this method can accommodate more students per square foot that any of the other methods. The square footage variable for peer tutor, tutor, programmed instruction, and computer assisted instruction training method classes were each assigned a value of 3.5, because there was no detectable difference in the amount of room needed for their use. These four tied rankings consumed 2, 3, 4, and 5 on the one to seven scale. The square footage variable for traditional practical exercise, and programmed practical exercise training methods were assigned a value of 6.5, because there

was no detectable difference in the amount of room needed to use them. These two tied rankings consumed positions six and seven on the scale, and completed the rankings for the square foot variable."

All the cost variables were assigned rank values using this procedure. The seven method cost classes and seven cost variables were then arranged in a table (Table B-3).

Using these seven rankings a mean rank for each method cost class can be computed. The remaining calculations were:

> "After the mean ranks were computed, the conditions for determining the relation of the cost intervals to the rank intervals was set. The lowest cost method was assigned a value of one, and the highest cost method a value of two. Since the number of intervals within a range of whole numbers is equal to the highest number in the range minus the lowest number in the range, the cost interval for Table B-2 is 2-1=1, and the rank interval of the seven variable scale is 7-1=6. The relationship of the one cost interval to the six rank intervals is the ratio of 1/6 which is .167. This ratio was used as a constant to compute the cost multiplier for the mean ranks of the method cost classes.
>
> The mean rank cost multiplier 'y' in Table B-2 was derived by subtracting one from the mean rank, multiplying the difference by the cost ratio and adding one, (e.g., y = (rank - 1 (x)) + 1). The number of hours of each method within the training cost option was multiplied by its cost factor to get the Method Cost Indicator (MCI) for the methods. The MCI for all methods within the training option were then summed yielding a Resident Option Cost Indicator (RMCI = ROCI)."

With the exception of AI, the cost method classes and cost variables were also applied to OJT and an analogous on-the-job option cost indicator, the JOCI was computed.

The two were then summed to obtain a cost indicator for each training option (TOCI).

TOCI = ROCI JOCI

or

Training option cost indicator = Resident cost option indicator + job option cost indicator

The TOCI is used to establish a ratio of one training cost option to another, giving the training manager as indication of relative cost. This enables the manager to select the most promising option or options for a complete CTEA effort. The procedures have been developed in both computer and manual mode.

Table B-3. Cost Ranking

METHOD COST CLASS	SQ FT	INST/ STU	SYS EQ	FURN	EXPEN	TNG AID DEV	MAT	AVERAGE RANK	Y
1. TRADITIONAL CLASSROOM	1.0	3.0	1.5	3.0	3.5	2.0	3.0	2.4	1.25
2. PEER TUTOR	3.5	4.5	3.5	3.0	3.5	2.0	1.5	3.1	1.33
3. TUTOR	3.5	7.0	3.5	3.0	3.5	2.0	1.5	3.4	1.40
4. PROGRAMMED INSTRUCTION	3.5	1.5	1.5	5.0	3.5	5.5	5.0	3.6	1.43
5. TRADITIONAL PRACTICAL EXERCISE	6.5	6.0	5.5	1.0	3.5	4.0	3.5	4.3	1.53
6. PROGRAMMED PRACTICAL EXERCISE	6.5	4.5	5.5	6.0	3.5	5.5	6.0	5.4	1.72
7. COMPUTER ASSISTED INSTRUCTION	3.5	1.5	7.0	7.0	7.0	7.0	7.0	5.7	1.74

Source: Pieper et al., p. II—46

PREDICTION OF TRAINING PROGRAMS FOR USE IN CTEA (1978)

(Jorgensen, C.C. & Hoffer, P.L. Prediction of Training Programs for Use in Cost Training Effectiveness Analysis. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 1978)

This report describes a model developed by Jorgensen and Hoffer (1978) that uses a systems approach to define training elements and their interactions within a CTEA setting. Following a set of logic flowcharts, the steps in CTEA conduct are depicted. Initial input is task and analysis data (ideally but not necessarily in ISD form). The model has been computerized. The model output is a cost-effectiveness ratio, obtained by dividing the estimated dollar cost of a program-generated training program by the program's estimated effectiveness ("an efficiency metric is used to estimate training effectiveness. The efficiency metric is an indication of the overall best fit between the training requirements of the task and the ability of various media and methods to satisfy these demands.")

The system overview was shown earlier in Figure III-1. As mentioned previously, the methodology begins with a task list or description that states the tasks and subtasks. After the tasks have been described, grouped and appropriate training methods and media selected (all by analyst/computer interaction) the selected alternative training programs are (or single program is) costed.

A unique cost module was not developed for this methodology. The TAEG 16 cost model developed for the Navy (Braby, Henry, et al., 1975) was used to cost the media and methods. As discussed earlier this model costs equipment and methods in terms of 37 variables (input to this computerized model). This cost model was, at the time of Jorgensen and Hoffer's work, in active use to cost training programs at the Army Air Defense School. This model is geared to institutional training (although adaptations might be possible) and does consider depreciation and LCC.

BDM's GENERAL MODEL/METHODOLOGY FOR CONDUCTING COST AND TRAINING EFFECTIVENESS ANALYSES (1976)

Vector Research, Inc., Cost and Training Effectiveness Analysis (CTEA): Handbook for Action Officers. Leavenworth, KS: BDM Services Company, 15 January 1976.

Vector Research, Inc., Development of a Cost and Training Effectiveness Analytical Models/Methodologies for Assessing Training Development & Products. Leavenworth, KS: BDM Services Company, 15 January 1976.

Vector Research, Inc., General Model/Methodology for Conducting Cost and Training Effectiveness Analyses. Leavenworth, KS: BDM Services Company, 10 December 1975.

In 1976 Vector Research, Inc., working as a subcontractor to BDM Services Co. prepared a CTEA model/methodology for TRADOC. BDM saw the training system as a number of subsystems, each to be assessed and costed; and an evaluation made of the aggregate total program (Fig. B-11).

As shown in Fig. B-11, it was based on a list of critical tasks and suggested that the CTEA study team consider individual and collective training in both unit and institution and by several methods. However, when BDM examined training for a number of Army systems they found a minimum of eight unique systems. These they identified as:

Large Group War Games Simulator

Individualized and/or Small Group Lesson Delivery System

Small Group Tactical Maneuver and Deployment Instructional Game

Program Directed Hands-On Job Performance Aid

Large Weapon System Practice Firing Adapter

Small Group Combat Engagement Simulator

Trouble Shooting Training Simulator

Small Weapon System Practice Firing Adapter

They then proceeded to integrate these eight types into their general model. The general model is shown in Fig. B-12. The authors of the methodology also prepared a CTEA handbook for action officers not formally trained for or experienced in performing CTEA. In spite of comprehensive overview shown in Fig. B-11, the guidebook offers no assistance to the action officer for the front-end analysis. He/she is directed to prepare a simple written description of the system being discussed, its purpose and general requirements. Then the guidebook directs the officer to the chpater discussing the system (of the eight) most like the one he/she has identified.

Although the model (Fig. B-12) shows a concurrent costing and effectiveness measurement effort, the description of detailed steps for each type system

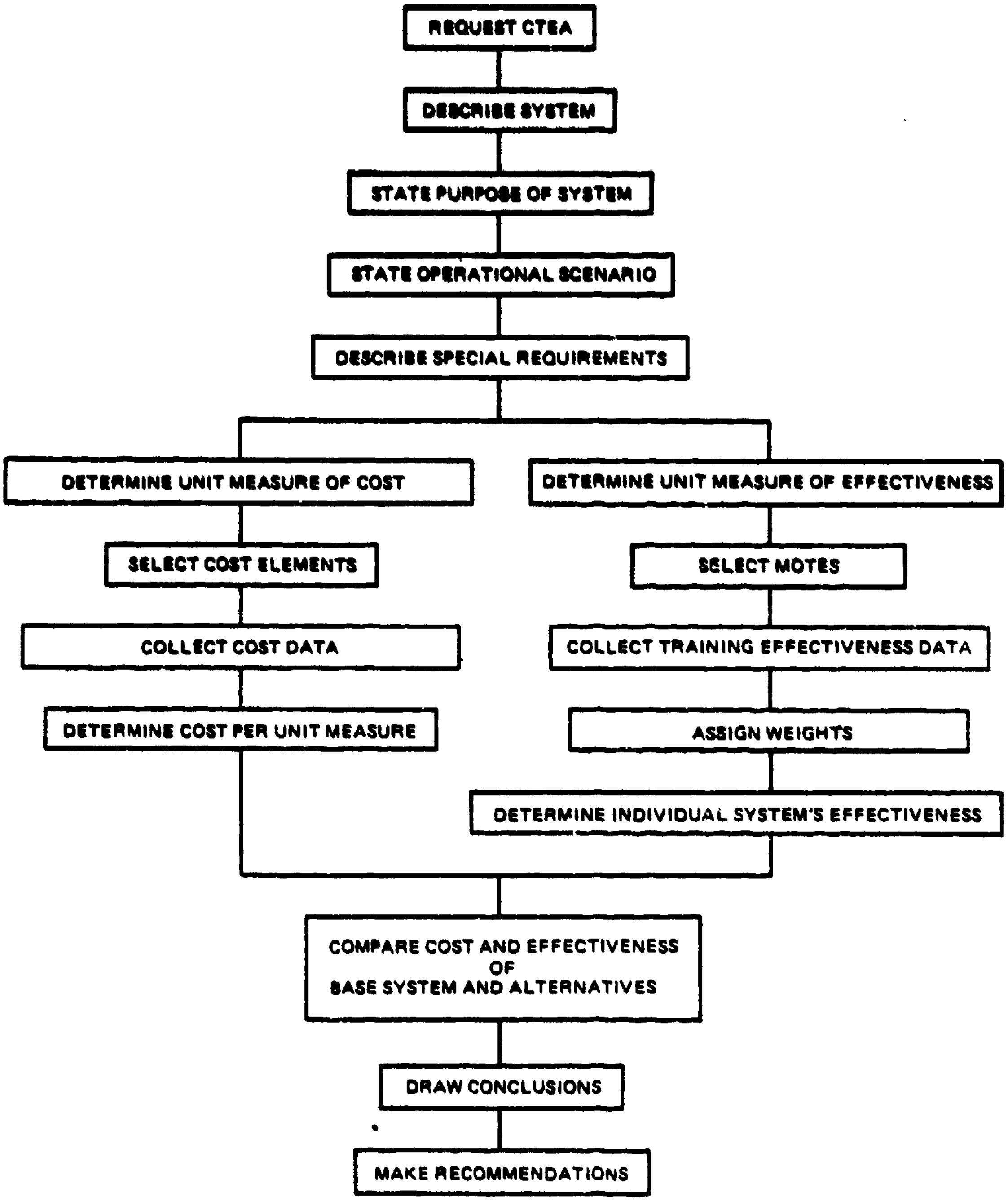
SYSTEM CONFIGURATION	TRAINING SYSTEM								
	TRAINING							EVALUATION	
	INDIVIDUAL						COLLECTIVE	INDIVIDUAL	COLLECTIVE
	UNIT				INSTITUTION (RS)		UNIT	UNIT	
MOS / CRITICAL TASK	JPA	STEP	FOJT	ISS	SPI	IC	ARTEP	SQT	ARTEP

JPA = Job Performance Aid
STEP = Self Teaching Exportable Package
FOJT = Formal On-Job Training
ISS = Installation Support School
RS = Resident School

SPI = Self Paced Instruction
IC = Instructor Centered
ARTEP = Army Training and Evaluation Program
SQT = Skill Qualification Test

(Source BDM, P 13)

Figure B-11. Training System Assessment Worksheet



Source: BDM, p. 111

Figure B-12. CTEA Flow Model

directs the analyst to address cost analysis <u>after</u> the effectiveness of alternative systems has been determined. In each case the cost analysis method is the same. The analyst selects the sample system most similar to the one(s) to be evaluated and then proceeds. Four forms and a checklist have been designed to ensure that all necessary steps in the CTEA have been completed.

In a method analogous to selection of a measure of training effectiveness (MOTE), the analyst sets a standard measurement of cost. (This always follows the determination of weighted MOTEs for the base case and all alternatives.) Table B-4 displays examples of standard measurement of cost and relevant cost elements for each of the eight training system types. When the analyst has defined the standard measure of cost, he/she enters this at the bottom of CTEA Form #2 and enters identification information at top of CTEA Form #3. Next, the appropriate cost elements are selected and their LCC cost estimated (also entered on Form #3). Suggested sources for these cost data are the Comptroller of the Army, the proponent school, or CTEA action officer estimation. Costs are summed for each training system, and a per unit cost (based on expected LC number of units of system used) calculated. These per unit costs are then multiplied by the effectiveness ratio and compared to the baseline cost and each other in a cost-benefit analysis. This completes the CTEA.

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Large Group War Games Simulator	The standard of measurement of cost is defined as the life cycle cost for conducting 500 controlled battalion level simulations per year for five years. Each simulation involves four computer terminals, used simultaneously to operate seven interactive programs and three historical files. The quantity to be used as the standard measurement of cost is cost per war game simulation.	Research and Development Feasibility Study System Design Pilot Programming Data Test and Evaluation Investment Hardware and Equipment Programming Date Operating and Support Computer Support Telecommunication Support Programming Support Administrative Support Logistic Support System Maintenance

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Individualized and/or Small Group Lesson Delivery System	The standard of measurement of cost is defined as the cost to provide 100 lessons of instruction to each of the 533 E3 and E4 personnel in a typical infantry battalion during the course of one year. The estimated useful life of lessons of instruction is five years. The quantity to be used as the standard of measurement for cost is cost per instructional lesson.	Research and Development Lesson Development Job Analysis Curriculum Design Lesson Review Investment Hardware Equipment Development of Software Lesson Material Lesson Publication and Printing Training Facilities Operating and Support Lesson Distribution Logistical Support Administrative Support Instructional Support Maintenance and Replacement

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Small Group Tactical Maneuver and Deployment Instructional Game	The standard of measurement of cost is the life cycle cost of providing annually 1000 simulation exercises of attack and defense tactical maneuvers involving two players and a controller. The estimated useful life of the exercise is five year. The quantity to be used as the standard of measurement of cost is cost per simulation exercise.	**Research and Development** Design Prototype Production System Test & Evaluation **Investment** Production System Test & Evaluation Spare Parts & Repair Parts **Operating and Support** Logistic Support Administrative Support Maintenance & Replacement Ammunition Cost

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Large Weapon System Practice Firing Adapter	The standard of measurement of cost is defined as the life cycle cost of providing 18 subcaliber training devices to each of 100 cannon units that will allow each crew to fire 500 subcaliber rounds annually for five years. The quantity to be used as the standard measurement of cost is the cost per battalion of artillery training enhancement.	<u>Research and Development</u> Design Prototype Production System Test and Evaluation <u>Investment</u> Production System Test and Evaluation Spare Parts and Repair Parts <u>Operating and Support</u> Administrative Support Maintenance and Replacement Ammunition Cost

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Program Directed Hands-On Job Performance Aid	The standard of measurement of cost is defined as the cost to provide 100 lessons of instruction to each of the 533 E3 and E4 personnel in a typical infantry battalion during the course of one year. The estimated useful life of a lesson of instruction is five years. The quantity to be used as the standard measurement of cost is the cost per instructional lesson.	**Research and Development** Lesson Development Job Analysis Curriculum Design Curriculum Review Lesson Review **Investment** Hardware Equipment Development of Software Lesson Material Lesson Publication and P[illegible] Training Facilities **Operating and Support** Lesson Distribution Logistical Support Administrative Support Instructional Support Maintenance and Replacement

Table B-4 Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Small Group Combat Engagement Simulation	The standard of measurement of cost is defined as the life cycle cost to conduct 10 attack/defense squad combat operations exercises annually for 100 typical infantry battalions for a period of ten years. The quantity to be used as the standard of measurement for cost is cost per squad combat operation exercise.	**Research and Development** Design Systems Test and Evaluation **Investment** Equipment Training Facilities **Operating and Support** Ammunition Cost Administrative Support Logistics Support Material Cost

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Trouble Shooting Trainer Simulator	The standard of measurement of cost is the life cycle cost of utilizing 1000 EFI Model 1051 communications skill trainer for teaching basic trouble shooting techniques to the beginning students in electronics equipment maintenance in resident and non-resident programs in the U.S. Army Signal School. The expected useful life of the device is an estimated five years at a utilization rate of 1000 hours per year per device. The quantity to be used as the standard of measurement of cost is cost per one hour of training in basic electronic trouble shooting techniques.	<u>Research and Development</u> Design Prototype Production System Test and Evaluation <u>Investment</u> Production System Test and Evaluation Spare Parts and Repair Parts <u>Operating and Support</u> Logistics Support Administrative Support Maintenance and Replacement

Table B-4. Examples of Standards of Measurement of Cost and Relevant Cost Elements for BDM CTEA Methodology's Eight Training System Types

Training System Type	Standard Measurement of Cost	Relevant Cost Elements
Small Weapon System Practice Firing Adapter	The standard of measurement of cost is defined as the life cycle cost of providing 18 .50 caliber subcaliber training devices (TDR 0104) for each of 100 armored battalions with an envisioned annual usage of 500 subcaliber rounds per crew. The expected useful life of each device is approximately 10 years. The quantity to be used as the standard measurement of cost is the cost per battalion of tank gunnary training enhancement.	**Research and Development** Design Prototype Production System Test and Evaluation **Investment** Production System Test and Evaluation Spare Parts and Repair Parts **Operating and Support** Ammunition Cost Logistics Support Administrative Support Maintenance and Replacement

MODIA: A METHOD OF DESIGNING INSTRUCTIONAL ALTERNATIVES FOR AIR FORCE TRAINING (1977)

(Carpenter-Huffman, P. MODIA: Vol. 1, Overview of a tool for planning the use of Air Force training resources, R-1700, Project Air Force Office (AF-RDQA), Washington, DC: Hq USAF, July 1977)

(Carpenter-Huffman, P. MODIA: Vol. 2, Options for course design, R-1701, Project Air Force Office (AF-RDQA), Washington, DC: Hq USAF, July 1977)

In the early 1970s the Rand Corporation undertook an extensive effort for the Air Force to develop a methodology for the design and cost analysis of an instructional system. MODIA is designed as a tool to help the AF manage resources for formal training by "systematically and explicitly relating quantitative requirements for training resources to the details of course design and course operation during the planning stage." (Carpenter-Huffman, 1977, p. 2) MODIA has been computerized and is designed specifically for use in the five Air Training Command (ATC) technical schools that account for 90% of the training load.

The computerized cost component of MODIA is called MODCOM. It operates from input selected by the user based on course operation reports output from the Resource Utilization Model (RUM). MODIA-designed alternatives will vary in both cost and effectiveness. They may then be compared with absolute standards such as budget constraints, minimum required effectiveness, and with each other.

Initial input to MODIA is the product of subject matter experts in planning and developing courses. Their path in definition of a training plan is not specified. In MODCOM, some of the requisite cost and manning factors are stored in the program while others are supplied by the user or planner. Total course costs for up to five years are included. Options on the included costs and their method of computation are available. The specific manpower and cost categories for which estimates are developed are:

Manpower

- Students
- Instructors
- Curriculum Personnel
- Hardware Maintenance Personnel
- Facilities Maintenance Personnel
- Training Administrative Personnel
- Base Operating Support Personnel
- Medical Personnel

Cost Categories

- Courseware Procurement
- Hardware Procurement
- Facility Construction

Pay and Allowances
    Students
    Instructors
    Support Personnel
Permanent Change of Station (PCS)/Temporary Duty (TDY)
Instructor Training
Miscellaneous Operating Expenses

Alternatives that may be examined are changes in the number of entrants; course duration; grade structure of the instructor force; the levels of staff and base support; pay and allowance factors; PCS/TDY factors; and the types of courseware and hardware used.

The author states that, although designed for use with MODIA, MODCOM may be operated independently. It produces five outputs:

- graduates by student type
- student and staff man-years
- courseware, hardware, and facility characteristics
- total course costs by functional element
- total course costs by program and appropriation

> MODCOM was designed to include 'relevant' costs, that is, only those costs which are both incremental (lie in the future) and variable (with respect to the decision to offer a particular course). Costs incurred as the result of past decisions and costs unaffected by the existence or size of the course under analysis are not considered relevant to the selection of an optimum course design.

Since it is intended for comparative purposes, all costs are in constant dollars. Inherited and residual value of resources are considered. It is not suitable for short-range budgetary planning, nonresident training, or courses given on an intermittent basis.

A large number of cost data elements are input by the user -- mostly average costs and rates or factors. Some such as personnel costs are calculated from such input as grade and pay scale matrices. Sample sources are shown in Table B-5.

Output samples are shown at Annex IV. Course costs are displayed as investment (courseware and/or hardware procurement and facility construction) and operating (pay and allowances, military/civilian personnel; PCS; TDY; instructor training; and miscellaneous. The final output translates costs into program and budget appropriation cost categories as defined by their functional cost elements.

Table B-5. Suggested Cost Data Sources, MODIA

SOURCES:

1. Keesler Technical Training Center, Keesler AFB, Missippi
2. *USAF Cost and Planning Factors*, AFR 173-10, Department of the Air Force, Headquarters USAF, Washington, D.C.
3. Rand-derived estimate(s).
4. Rand estimates based on data in *The Audio-Visual Equipment Directory*, National Audio-Visual Association, Inc., Fairfax, Va.
5. Comptroller, Headquarters ATC, Randolph AFB, Texas
6. EPIEGRAM (newsletter of the Educational Products Information Exchange Institute, N.Y.), No. 13, April 1, 1973
7. DCS Plans, Directorate of Manpower and Organization, Headquarters ATC, Randolph AFB, Texas
8. *ATC Cost Factors Summary*, Department of the Air Force, Headquarters ATC, Randolph AFB, Texas
9. OMB Circular No. A-94, "Discount rates to be used in evaluating time-distributed costs and benefits," March 27, 1972, Office of Management and Budget, Washington, D.C.

COORDINATION OF HUMAN RESOURCE TECHNOLOGIES (CHRT) (1978)

Goclowski, J.C., King, G.F., Ronco, P.G., & Askren, W.B. Integration and Application of Human Resource Technologies in Weapon System Design: Coordination of Five Human Resource Technologies. AFHRL-TR-76-6 (I) Brooks AFB, TX: U.S. Air Force Systems Command, 1978.

Goclowski, J.C., King, G.F., Ronco, P.C., & Askren, W.B. Integration and Application of Human Resource Technologies in Weapon System Design: Processes for the Coordinated Application of Five Human Resource Technologies. AFHRL-TR-76-6 (II) Brooks AFB, TX: U.S. Air Force Systems Command, March 1978.

Goclowski, J.C., King, G.F., Ronco, P.G., & Askren, W.B. Integration and Application of Human Resource Technologies in Weapon System Design: Consolidated Data Base Functional Specification. AFHRL-TR-76-6 (III) Brooks AFB, TX: U.S. Air Force Systems Command, May 1978.

Goclowski and his associates, in work conducted for the Air Force Human Resources Laboratory at Wright-Patterson Air Force Base, OH, have developed (1978) a methodology for coordinating five human resource technologies (maintenance manpower modeling (MMM), instructional system development (ISD), job guide development (JGD), system ownership costing (SOC), and human resources in design trade-offs (HRDT). This methodology (CHRT) quantified the reliability, maintainability, manpower, training and JGD requirements for a weapon system. It was designed for use by planners early in the system acquisition and brings the influence of the aforementioned quantified factors to bear on design, maintenance, operations and support concepts and permits estimation of ownership costs.

CHRT, termed a predictive and product-oriented methodology, depends on four basic activities.

1. Development of a consolidated data base.
2. The integrated requirements and task analysis.
3. ISD and JGD product development.
4. The impact analysis.

Task requirements are to be developed very early; a traditional, integrated task analysis, during full scale development. CHRT may be reiterated for alternative approaches. IS and JG products follow the lost task analysis. The computerized methodology was to be tested using data from the advanced medium STOL transport (AMST) and the methodology refined. (A report on this work has not been identified.)

An objective of this development was the production of weapon system operating and support costs. To this end, the method is subordinate to the ILS. The ILS plan, properly executed, is cited as the primary data source for ten subordinate categories, including (inter alia) personnel and training. However, the detailed data required for the logistic support analysis (LSA) do not become available until the full-scale development phase. The CHRT process is planned to fill a similar need for the conceptual and validation phases and support the detailed design in later phases.

The costing portion of CHRT, the SOC, was not fully developed at the time of this report. The authors state that more comprehensive models are needed to identify the "real ownership cost drivers." As developed, the SOC technique builds on data gathered for or derived from operation of the MMM, ISD and JGD models. A flow diagram of SOC is shown in Fig. B-13. When the trade-off portion of the methodology is exercised, costs may be constrained. The authors recognize that equation and models for obtaining cost estimates are not standardized and that sources of data do not always adequately reflect the system under consideration.

Task is basic to the CHRT. It is defined as "an action or reaction related to equipment, e.g., operate aircraft, remove radio, replace transistor. The conclusion that should be drawn from the example is that a task may be either general or very specific and that most tasks imply subtasks." (Goclowski et al., 1978 (a))

Task is more precisely defined in Vol. II as: "A composite of related activities (behaviors) performed by an individual and directed toward accomplishing a specific amount of work within a specific work context. These activities usually occur in temporal proximity with the same displays and controls and have a common purpose. Each task has a goal."

General data requirements for the SOC are shown in Table B-6 along with other essential data for exercising the CHRT. Forty-one items (of 42 data items and 27 sub-items) are shown applicable to the SOC. Most of these are derived from MMM, ISD, and JGD (26 items) and others are input to HRD (9 items). Those unique to SOC are unit cost goals, D-T-G goals, R/W consideration, and a number of costs (manuals, LRU spares, aircrew, fuel, depot repairs, faciities, inventory technical records data, on/off equipment maintenance, and maintenance material. As may be seen, SOC derives costs for more than the training system. SOC is designed to translate human resource data to cost data on a system or subsystem basis.

In the conceptual and validation phase the task list is obtained from general maintenance requirements, a knowledge of equipment comparability, maintenance event data, maintenance activity data, interviews with maintenance personnel, comparable tech data and training resources, operations and mission concepts and plans, operations requirements, comparable training courses and a review of existing training resources. Data are separated into maintenance and operational categories and are stored in task condition matrices.

In the full scale development phase, a general task analysis is supposed to be conducted for both maintenance and operations and following ISD and JGD, a detailed task analysis.

It is anticipated that through experience cost estimating formulae for the SOC will be developed. An example is shown in Annex VI(1). The cost model (a LCCM) is shown in Fig. B-14. The authors caveat that the SOC must be reviewed for applicability to each weapon system where it is used and if necessary tailored to fit a particular system during the conceptual phase. It requires numerical data input for each element (Annex V(2)). The suggested sources are standard

Table B-6. Data Requirements for SOC

HUMAN RESOURCE TECHNOLOGY DATA

DATA ITEM	HRDTT	MMMT	JGDT	ISDT	SOCT
1. Viable Design Alternatives	X				
2. Other Alternatives	X				
a. Training	X		X	X	
b. Manuals	X		X	X	X
c. SE	X	X	X	X	X
d. Maintenance	X	X	X	X	X
e. Operations	X			X	X
3. Support Goals					
a. Reliability		X			
b. MMH/FH		X	X	X	X
c. Availability		X			
d. UDL		X	X	X	X
e. Spares		X	X	X	X
4. Unit Cost Goals					X
5. D-T-G Goals					X
6. RIW Considerations					X
7. Multi-National Considerations	X				
8. Annual Flying Hours		X			X
9. Number of Bases		X		X	X
10. Number of Aircraft		X		X	X
11. Crews per Aircraft	X	X	X	X	X
12. Crewmen per Crew	X	X	X	X	X
13. Crew Makeup	X	X	X	X	X
14. Missions		X		X	
15. Mission Essential Elements	X				
16. Performance	X	X			
17. Configuration	X	X	X	X	X
18. Construction	X	X	X	X	X
19. Expected Operational Life		X			X
20. Maintenance Probabilities		X	X	X	X
21. Maintenance Times		X	X	X	X
22. Skill Category		X	X	X	X
23. Skill Level		X	X	X	X
24. Crew Size		X	X	X	X
25. SE Utilization		X	X	X	X

Table B-6. Data Requirements for SOC (Continued)

HUMAN RESOURCE TECHNOLOGY DATA

DATA ITEM	HRDTT	MMMT	JGDT	ISDT	SOCT
26. Safety Hazards	X	X	X	X	
27. Available Personnel					
a. Years of Service				X	X
b. Labor Rate					X
c. Scores			X	X	
d. Retention Rate			X	X	
e. Predictions			X	X	
28. Task Frequency			X	X	
29. Task Criticality			X	X	
30. Task Difficulty			X	X	
31. Degree of Proceduralization			X	X	
32. Content of Task Information			X	X	
33. Job Guide Concept			X	X	
34. Job Guide Status			X		
35. Manual Content			X		
36. Training Concept			X	X	
37. Training Status				X	
38. Course Content				X	
39. Time to Train				X	
40. Quantity to Train				X	X
41. Training Resources				X	X
42. Cost					
a. SE Investment			X		X
b. Manual Investment					X
c. LRU Spares Investment					X
d. Aircrew					X
e. Fuel					X
f. Depot Repairs					X
g. Facilities					X
h. Inventory					X
i. Technical Record Data					X
j. On/Off Equipment Maintenance					X
k. Training				X	X
l. Maintenance Material					X

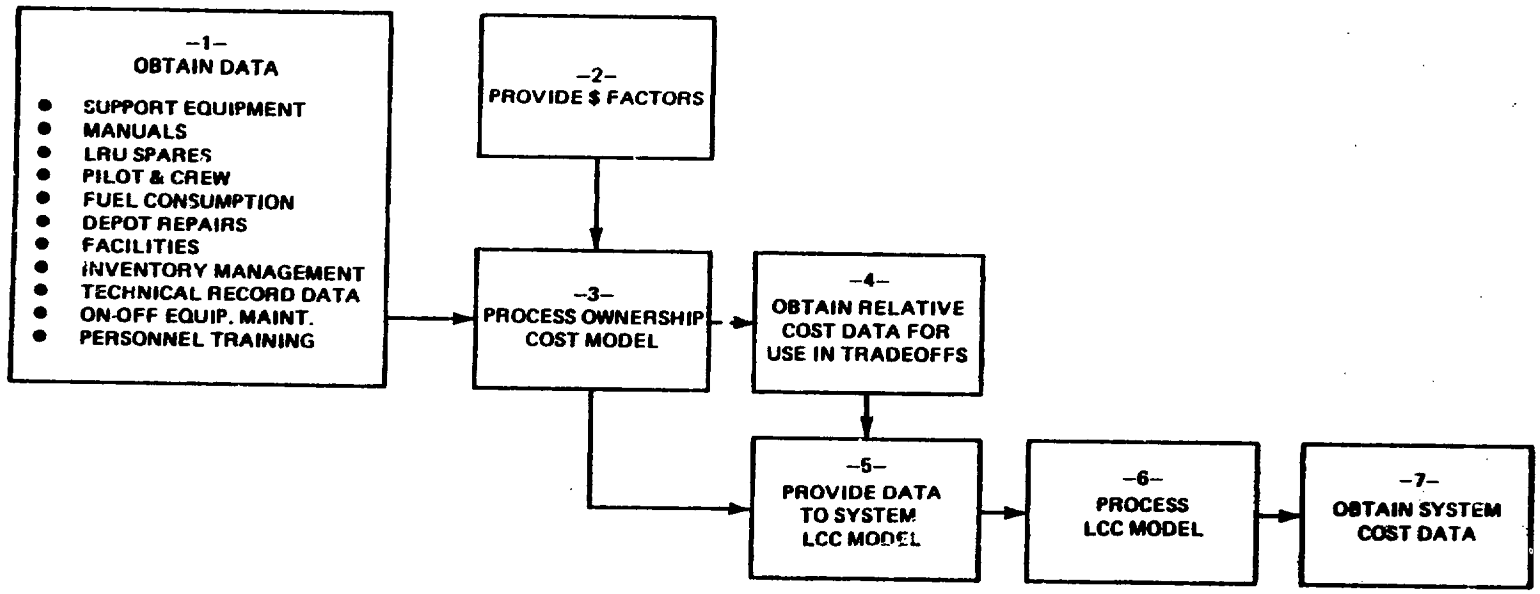


Figure B-13. System Ownership Cost Flow Diagram

SYSTEM OWNERSHIP COST* =

SUPPORT INVESTMENT COSTS* + OPERATING COSTS* + SUPPORT COSTS*

SUPPORT INVESTMENT COSTS* = $C_{SE} + C_{JG} + C_{LS}$

C_{SE} = COST OF SUPPORT EQUIPMENT
C_{JG} = COST OF JOB GUIDES
C_{LS} = COST OF LRU SPARES

O&S OPERATING COSTS = $C_{PC} + C_{FC}$

C_{PC} = COST OF AIRCREW
C_{FC} = COST OF FUEL

O&S SUPPORT COSTS = $C_{DR} + C_{MM} + C_{FA} + C_{IM} + C_{TR} + C_{EM} + C_{PT}$

C_{DR} = COST OF DEPOT REPAIRS

C_{FA} = COST OF FACILITIES
C_{IM} = COST OF INVENTORY MANAGEMENT
C_{TR} = COST OF TECHNICAL RECORD DATA
C_{EM} = COST OF ON-OFF EQUIPMENT MAINTENANCE
C_{PT} = COST OF PERSONNEL TRAINING

*All costs expressed in annual dollars, i.e., dollars/year.

Figure B-14. The System Ownership Cost Model for CHRT

government offices/documents such as pay and allowance tables, cost factor manuals and regulations. Equations for each cost shown in Fig. B-14 are included in Goclowski et al., 1978 (c). As outlined above, the task list creates the training program with its requirements for job guides, personnel training, media, etc. and these are costed along with all other support costs. Thus, although the life cycle training costs are included and calculated, they do not appear as unique items in the final output.

AN AIR DEFENSE CTEA METHODOLOGY (1978)

Hawley, J.K. and Thomason, S.C. Development of an Air Defense Cost and Training Effectiveness Analysis (CTEA) Methodology (for the AN/TSQ-73): Vol I - CTEA Within the Life cycle System Management Model. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 18 December 1978.

__________, Vol. II, Demonstration CTEA on the AN/TSQ-73.

Earlier we referred to a methodology developed by Hawley and Thomason (1978). This conceptual model was designed to perform CTEA at the points required by the LCSMM. It was partially demonstrated on an existing system (Hawley and Thomason, 1978a). The research documentation caveats that detailed procedures and analysis techniques must be developed for each of the points in the LCSMM to produce a 'full blown process' model from the conceptual model.

Hawley and Thomason prepared both a CTEA methodology and list of events/stages of the LCSMM. Then they integrated these two series of activities since they are concurrent processes. In their opinion this integration is necessary since hardware-related and training-related activities are so interactive that 'imbalances in development can easily cause CTEA to become a relatively futile gesture'. These analysts also start with a list of tasks or activities generated from analytical study of the materiel system hardware. They state that, for conceptual systems, an activities list is developed as part of the training input to the letter of agreement (LOA). After the development of the hardware prototypes, the task list is obtained from the Job/Task Analysis; the job conditions, from the Mission Analysis; the standards, empirically or judgmentally derived.

The next important step in this methodology is the formulation of EEA to assess effectiveness of the training system. For each EEA, methods of training effectiveness (MOTE) and measures of resource requirements (MTRR) are to be specified. The MTRR, the resources required to reach the training objectives, constitute the cost model input.

Examples of categories of MTRR are the following:

1. Operating requirements for a proposed training system or methodology:

   o Instructors
   o Students
   o Facilities

2. Support requirements:

   o Personnel
   o Materiel
   o Supplies consumed
   o Parts expended

3. The reliability, availability, and maintainability (RAM) of the training equipment. Included in this assessment is the maintenance policy for complex training devices.

Suggested sources for existing data are:

1. Past studies and performance data (e.g., DT/OT, SQT, ARTEP, etc.) on similar or ancestral systems.

2. Completed tests (e.g., DT/OT) on the subject system.

3. Task/function analysis data.

4. Training test scores.

5. SQT and ARTEP results.

6. Secondary data sources.

   o Literature
   o Institutional data bases
   o Expert opinion/judgment

The analyst is advised to be aware that:

1. Training methodology must be specified at a level of detail that can be reliably costed.

2. Cost estimates should include initial (set-up or sunk) costs as well as recurring costs.

3. Some COEA may require training LCCE (especially true if a large initial investment is to be made in equipment subject to depreciation and/or obsolescence).

Input cost data are categorized as falling into these categories:

1. Facilities -- land, buildings, etc.
2. Equipment - training and support
3. Instructional material - development and acquisition
4. Personnel - instructors and training support
5. Students
6. Supplies
7. Miscellaneous (e.g., travel)

Hawley and Thomason also recognize the importance of the training concept to the cost. They advise the cost analyst to include in his cost data requests, at a minimum, the following:

1. The training concept -- a description of how the training will be carried out, instructional methods to be employed, and so forth.

2. The make, model, quantity, and quality of materiel required.

3. The quantity, grade, and skill level of personnel required.

4. The time requirements and materiel usage data -- the length of course, facilities required, supplies expended, and so forth.

They state that training resources cost quotes should be expressed in constant year-dollars and that DOD policy specifies that for CTEA the base cost year is the fiscal year following the calendar year in which the study is scheduled to be completed. That is, the base cost year is the year the full-scale or limited production of the materiel system is projected to begin (e.g., between ASARC III and IOC). (A reference for ths information is not cited.)

Other costs projections recommended are:

1. Sunk costs: Cost invested in tangible assets that can be recovered only by use of the assets over their service life.

2. Fixed costs: Costs tnat are constant in total amount regardless of production volume, e.g., depreciation in building space occupied.

3. Variable costs: Costs that tend to vary proportionately to the activity in the function involved, e.g., direct materials, direct labor, operating supplies, and so forth.

4. Semivariable Costs: Costs having a fixed and a variable component, such as the cost of maintenance and repair on a shut down facility.

They also say that provision should be made for including LCCE to project the cost of the training program over the life of the materiel system (or over some reasonable portion of it). The life cycle cost methodology should also include the capability for discounting training cost over the life of the materiel system.

This research holds that the accounting and discounting requirements are generally available in existing cost models (e.g., the TECEP costing model presented in TAEG Report No. 1) and that in the absence of special cost analysis requirements, one of the existing procedures be used. They warn, however, that the nature of the available training cost data must match the input requirements of the costing model. Obversely, if the EEA require features not available in the "canned" model, it must be adapted or not be used. This methodology also recommends that specific comparisons can be made to highlight critical cost considerations and cost-related issues that require further exploration in the form of sensitivity analyses identified. They advise sensitivity analyses, defined as investigations of the effect on training cost and resources if certain assumed parameters take on different values. As examples of such parameters they cite:

1. Training equipment RAM characteristics.

2. Instructor salaries (e.g., converting from military to civil service instructors or from enlisted personnel to officers).

3. Student selection factors (e.g., recruiting a larger proportion of category III or IV students resulting in a higher attrition rate or more remedial time).

The training cost sensitivity analyses are conducted to identify particularly sensitive parameters or assumed values so that special care can be taken in estimating these parameters more closely. The objective is to select training methodologies that are cost-effective for most of the range of likely values for these assumed parameters.

In a second volume reporting this research (Hawley and Thomason, 1978(b)), the authors attempted to exercise the methodology using data from a developed system (the AN/TSQ-73). A number of problems (believed typical) were found -- LCSMM not strictly adhered to: lack of coordination between hardware system development (SD) and ISD (far behind HDS); formal task list/analysis non-existent; TM in draft and full of errors. The HSD had passed through a third DT/OT and it was too late for CTEA to be conducted for input to the final COEA. Other attendant problems were present.

Because of the 'primitive' state of ISD, the researchers chose to use Jorgensen and Hoffer's (1978) training consonance method (an estimate of compatibility of task and training, theoretically correlated with training effectiveness: two training courses -- the Army's and the contractor's -- were proposed and were the candidates for exercising the CTEA methodology.

The cost portion of the CTEA was not exercised. Programmed instruction for one proposed system was the only suggested difference. Although found to be of higher acquisition cost, this material was of insignificant cost when amortized over the life of the system.

APPENDIX C

LIST OF ABBREVIATIONS AND ACRONYMS

AD	Advanced Development
AIT	Advanced Individual Training
AP	Acquisition Plan
APM	Army Program Memorandum
AR	Army Regulation
ARTEP	Army Training and Evaluation Program
ASARC	Army Systems Acquisition Review Council
ASI	Additional Skill Identifier
ATM	Analogous Task Method
BDM/CARAF	The BDM Service Company Combined Arms Research and Analysis Facility
BOIP	Basis of Issue Plan
BOIPT	Basis of Issue Plan - Tentative
BT	Basic Training
CDB	Consolidated Data Base
C/E	Cost Effectiveness
CFP	Concept Formulation Package
CHRT	Coordinated Human Resources Technology
COEA	Cost and Operational Effectiveness Analysis
CTEA	Cost and Training Effectiveness Analysis
DA	Department of the Army
DARCOM	U.S. Army Materiel Development and Readiness Command
DCP	Decision Coordinating Paper
DRIMS	Diagnostic Rifle Marksmanship Simulators
DSARC	Defense System Acquisition Review Council
DT	Development Test
DT/OT	Development Test/Operational Test
DTD	Directorate of Training Developments
FYDP	Five Year Defense Plan
HRDT	Human Resources in Design Trade-Offs
ILS	Integrated Logistic Support
IPR	In-Process Review
IPS	Integrated Personnel Support
IRTA	Integrated Requirements and Tasks Analysis
ISD	Instructional Systems Development
ISP	Integrated Support Plan
ITC	Institutional Training Cost
ITDT	Integrated Technical Documentation and Training
ITP	Individual Training Plan
ITV	Improved TOW Vehicle
JGD	Job Guide Development
LCC	Life Cycle Costs
LCCE	Life Cycle Cost Elements
LCSMM	Life Cycle System Management Model
LOA	Letter of Agreement
LOGCEN	Logistics Center
LR	Letter Requirement
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
MENS	Mission Element Needs Statement
MILPERCEN	Military Personnel Center
MMM	Maintenance Manpower Modeling
MOS	Military Occupational Specialty

MODIA	Method of Designing Instruction Alternatives
MOD	Modification
MOTE	Measures of Training EffectivenessNET
MPA	Military Personnel, Army
NET	New Equipment Training
OAP	Outline Acquisition Plan
ODP	Outline Development Plan
OICTP	Outline Individual Collective Training Plan
OJT	On-the-job Training
OMA	Operations and Maintenance, Army
OSUT	One Station Unit Training
OT	Operational Test
P_h	Probability of Hit
PIP	Product Improvement Program
PM	Project Manager
POI	Program of Instruction
PQQPRI	Provisional Qualitative and Quantitative Personnel Requirements Information
PROC	Procurement
QQPRI	Qualitative and Quantitative Personnel Requirements Information
RAM	Reliability, Availability, Maintainability
RDTE	Research, Development, Test and Evaluation
RFA	Rimfire Adapter
ROC	Required Operational Capability
RTE	Relative Training Effectiveness
RUM	Resource Utilization Model
SAT	Systems Approach to Training
SOC	System Ownership Cost
SQT	Skill Qualification Test
TASA	Task and Skill Analysis
TAEG	Training Analysis and Evaluation Group
TCA	Training Consonance Analysis
TECEP	Training Evaluation Cost Evaluation Program
TDDA	Training Developers Decision Aid
TDIS	Training Developments Information System
TEEM	Training Efficiency Estimation Model
TM	Technical Manual
TOCI	Training Option Cost Indicator
TOE	Table of Organization and Equipment
TQQPRI	Tentative Qualitative and Quantitative Personnel Requirements Information
TRADOC	Training and Doctrine Command
TRAINVICE	Training Device Effectiveness Model
TRAM	Training Analysis Model
TRAMOD	Training Requirements Analysis Model
TSD	Training System Design
TSM	TRADOC System Manager
TTC	Total Training Cost
UI	User Interface
UTC	Unit Training Cost
WSTEA	Weapon System Effectiveness Analysis

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1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, COMBAT DEVELOPMENT
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, TRAINING DEVELOPMENT
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